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A two dimensional comparative study of the soft tissue profile of a group of post operative orthognathic patients to a control group

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degree of MSc of the faculty of Medicine, University of Glasgow.
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Abstract

Orthognathic surgery aims to correct underlying dentofacial deformities and improve facial aesthetics. This study was designed to compare the two-dimensional (2D) lateral facial soft tissue profiles of a group of post-surgical patients (orthognathic group) to a control group of individuals recruited from the local population in the West of Scotland. The relative attractiveness of 112 volunteers (61 females, 51 males), recruited from the local population and aged 18 to 35 years, were rated by a lay panel (four males, four females) who assessed three dimensional (3D) facial images of the volunteers using a Visual Analogue Scale. 16 males and 24 females, rated as being “attractive” and “most attractive” were selected to form the control group. The orthognathic group of 33 patients (17 females, 16 males) was recruited from the Dentofacial Deformity Clinic based at the Glasgow Dental Hospital and the Southern General Hospital, Glasgow. Right lateral 2D facial profile photographs of the control group and the orthognathic group were taken, and digital identification of soft tissue facial lateral profile landmarks completed. Outcome measures were angular, linear horizontal and vertical linear measurements taken from the soft tissue landmarks. Comparison of control males to control females showed that the males had longer faces and more prominent chins than the females. The male orthognathic group had more protrusive lips and chins compared to the male control group, but overall had a similar facial morphology. The female orthognathic group had smaller nasiolabial angles, a longer mid- and lower facial heights and lips and chins which were more prominent than the female control group.

Contents

Abstract.....	1
Contents	2
List of Tables	6
List of Figures.....	9
Acknowledgements.....	11
Declaration.....	12
1 Literature Review.....	14
1.1 Introduction	14
1.2 Dentofacial Deformity.....	15
1.2.1 Incidence of Dentofacial Deformity.....	15
1.2.2 Treatment Need of Dentofacial Deformity	16
1.2.3 Why Patients Seek Treatment	18
1.2.4 Benefits of orthognathic surgery.....	21
1.3 Facial attractiveness	22
1.3.1 Definition of Beauty.....	22
1.3.2 Difference between beauty and attractiveness	22
1.3.3 History of attractiveness and proportions	23
1.3.4 Basis of facial aesthetics	24
1.3.5 Components of attractiveness	24
1.3.6 Culture and beauty	27
1.3.7 Social implications / importance of facial aesthetics	28
1.3.8 Associations of attractiveness	29
1.3.9 Summary	30
1.4 Objective evaluation of facial attractiveness.....	31
1.4.1 Use of photographs for facial measurements	31
1.4.2 Standardisation of photographs.....	32
1.4.3 Photographic reproducibility.....	33
1.4.4 Photographic validity	34
1.4.5 Sources of errors in photogrammetry,identification of soft tissue landmarks	34
1.4.6. Sources of errors in photogrammetry – subject positioning	35
1.4.7 Sources of errors in photogrammetry – photographic distortion	36

1.4.8	Summary	36
1.5	Previous studies analysing soft tissue profile	37
1.5.1.	Age	37
1.5.2	Inclusion criteria.....	37
1.5.3	Differences in methods	38
1.6	Subjective evaluation of facial attractiveness.....	42
1.6.1	Lay panel versus expert panel	42
1.6.2	Effect of gender and race	44
1.6.3	Panel number.....	45
1.6.4	Conclusion	46
1.7	Use of the visual analogue scale (VAS)	47
2	Rationale and aims of the study	53
2.1	Rationale for the study	53
2.2	Aims of the study	55
3	Materials and Methods Part 1	57
3.1	Study design	57
3.2	Subjects	57
3.2.1	Inclusion Criteria.....	58
3.2.2	Exclusion Criteria.....	58
3.3	Materials	58
3.3.1	The 2D Imaging System.....	58
3.3.2	Calibration.....	60
3.3.3	Image capture	60
3.4	Lay Panel Members	61
3.5	Rating of Images	63
3.6	Ranking of Images.....	63
3	Materials and Methods Part II	65
3.7	Study Design	65
3.8	Subjects	65
3.8.2	Exclusion Criteria.....	66
3.8.3	Sample size calculation	66
3.9	Materials	67
3.9.1	Error study.....	67

3.10	Analysis of Digital Images	75
3.10.1	Construction of a true vertical line passing through subnasale.....	75
3.10.2	Magnification calculation.....	75
3.10.3	Landmark Identification.....	76
3.11	Measurements	76
3.11.1	Facial Angles.....	76
3.11.2	Linear Horizontal Distances.....	76
3.11.3	Facial Harmony Value	80
3.11.4	Linear Vertical Distances.....	80
3.12	Statistical Analysis.....	84
4	Results Part I	86
4.1	Sample characteristics	86
4.2	Error of the method	86
4.3	Control males and control females	89
4	Results Part II	96
4.4	Sample characteristics	96
4.5	Control males and orthognathic males	96
4.4	Control females and orthognathic females	101
5	Discussion Part I	112
5.1	The control group	112
5.1.1	Patient recruitment	112
5.1.2	The control group.....	112
5.1.3	Use of a lay panel.....	113
5.1.4	Panel composition	113
5.2	Methodology	114
5.2.1	Assessment of facial aesthetics by use of the VAS.....	114
5.2.2	Use of profile photographs.....	115
5.2.3	Soft tissue landmark and measurement choice	117
5.2.4	Intra-operator reproducibility of landmark identification	117
5.3	Analysis of the attractive group.....	118
5.4	Future considerations	131
5	Discussion Part II	131
5.5	The orthognathic group	132

5.5.1	Patient recruitment	132
5.5.2	Surgical procedures.....	132
5.6	Male orthognathic group compared to the male control group	133
5.7	Female orthognathic group compared to the female control group	135
5.8	Future considerations	136
6	Conclusions	139
6.1	First Aim.....	139
6.2	Second Aim	140
7	Appendices	142
7.1	Appendix I – Copy of the Ethics letter	142
7.2	Appendix II - Rating VAS instructions	144
8	References	147

List of Tables

Chapter 1 Literature Review

Table 1.1	Summary with details of previous studies on lateral facial soft tissue measurements	40-41
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Chapter 3 Materials and Methods

Table 3.1	Soft tissue landmarks used in the study	69
Table 3.2	Landmarks used to define clinical angular measurements	70
Table 3.3	Landmarks used to define clinical linear horizontal measurements	71
Table 3.4	Landmarks used to define clinical facial harmony values and the linear horizontal differences between landmarks relative to the True Vertical	72
Table 3.5	Landmarks used to define clinical linear vertical measurements	73

Chapter 4 Results

Table 4.1	Reproducibility of landmark identification, X coordinates	88
Table 4.2	Reproducibility of landmark identification, Y coordinates	89
Table 4.3	Angular measurements (degrees) for control males and females including means, standard deviations and tests for significant differences between control males and control females	91
Table 4.4	Linear horizontal measurements (mm) relative to True Vertical (TV) for control males and females, including means, standard deviations and tests for significant difference between control males and females	92

Table 4.5	Facial harmony values (mm), the linear horizontal difference between landmarks as calculated from the True Vertical (TV) for control males and females including means, standard deviations and tests for significant differences between male and female control groups	95
Table 4.6	Linear vertical measurements (mm) for control males and females including means, standard deviations and tests for significant differences between control males and females	96
Table 4.7	Angular measurements (degrees) for control males and orthognathic males including means, standard deviations and tests for significant differences between control males and orthognathic males	98
Table 4.8	Linear horizontal measurements (mm) relative to True Vertical (TV) for control males and orthognathic males including means, standard deviations and tests for significant differences between control males and orthognathic males	100
Table 4.9	Facial harmony values (mm), the linear horizontal difference between landmarks as calculated from the True Vertical (TV) for control males and orthognathic males, including means, standard deviations and tests for significant differences between control males and orthognathic males	101
Table 4.10	Linear vertical measurements (mm) for control males and orthognathic males including means, standard deviations and tests for significant differences between control males and orthognathic males	104
Table 4.11	Angular measurements (degrees) for control females and orthognathic females including means, standard deviations and tests for significant differences between control females and orthognathic females	105

Table 4.12	Linear horizontal measurements (mm) relative to True Vertical (TV) for control females and orthognathic females including means, standard deviations and tests for significant differences between control females and orthognathic females	108
Table 4.13	Facial harmony values (mm), the linear horizontal difference between landmarks as calculated from the True Vertical (TV) for control females and orthognathic females including means, standard deviations and tests for significant differences between control females and orthognathic females	109
Table 4.14	Linear vertical measurements (mm) for control females and orthognathic females including means, standard deviations and tests for significant differences between control females and orthognathic females	111
Chapter 5	Discussion	
Table 5.1	Comparison of angular measurements between the present study and the main comparative studies	121-122
Table 5.2	Comparison of linear horizontal measurements relative to a True vertical reference line through subnasale between the present study and the main comparative studies.	124
Table 5.3	Comparison of harmony value measurements between the present study and the main comparative studies.	129
Table 5.4	Comparison of vertical measurements between the present study and the main comparative studies.	132

List of Figures

Chapter 3	Materials and Methods	
Figure 3.1	Schematic diagram showing the photographic set-up.	60
Figure 3.2	Photograph showing right lateral profile view with the subject in natural head position with calibration ruler.	63
Figure 3.3	Diagram of a right profile image with competent lips showing the soft tissue landmarks and the True Vertical (TV) reference line used.	74
Figure 3.4	Diagram of a right profile image with incompetent lips showing the soft tissue landmarks and the True Vertical (TV) reference line used.	75
Figure 3.5	Diagram of a right profile image showing the angular measurements.	78
Figure 3.6	Diagram of a right profile image showing the angular measurements used.	79
Figure 3.7	Diagram of a right profile image showing the linear horizontal measurements relative to a True Vertical reference line used.	80
Figure 3.8	Diagram of the right profile image showing the harmony value measurements used.	82
Figure 3.9	Diagram of a right profile image with competent lips showing the linear vertical measurements used.	83
Figure 3.10	Diagram of a right profile image with incompetent lips showing the linear vertical measurements used.	84
Chapter 5	Discussion	
Figure 5.1	Diagram showing the horizontal measurements relative to a TV for the present and previous studies for females, showing the common landmarks	125

Figure 5.2 Diagram showing the horizontal measurements relative to a TV for the present and previous studies for males, showing the common landmarks

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Declaration

This thesis is the original work of the author.

Chapter One

Literature Review

1 Literature Review

1.1 Introduction

Orthognathic surgery is defined as the surgical correction of a dentofacial deformity (Proffit and White, 1990) and aims to improve facial and dental aesthetics resulting in a more harmonious facial skeletal and soft tissue relationship and establishing a stable functional occlusion (Barnard and Birnie, 1990).

Orthognathic surgery enables optimal correction of aetiological factors, whereby the underlying skeletal discrepancy is corrected. Advances in diagnosis, treatment planning, orthodontic mechanics and surgical technique have enabled the use of bimaxillary surgical procedures to correct facial skeletal discrepancies in all three planes of space. The treatment does not just change the bony relations of the facial structures, but it also affects the overlying soft tissues and may alter the patient's appearance (Finlay *et al.*, 1995). Orthognathic surgery is becoming more widely available and accepted as a treatment for facial anomalies and malocclusions as is indicated by the increasing demand (Jensen, 1978; Cunningham, 1999).

Orthognathic surgery has evolved from an emphasis on achieving the optimal functional occlusion to achieving improvements in facial aesthetics (Sarver and Ackerman, 2000). Restoration of the orthognathic form of the face ultimately depends upon achieving the ideal facial aesthetics of the individual patient.

1.2 Dentofacial Deformity

Dentofacial deformity has been defined as facial and dental disproportions great enough to significantly affect the individual's quality of life and is likely to require both orthognathic and orthodontic treatment (Proffit and White, 1991). A dentofacial deformity exists when a patient's facial proportions and dental malocclusion deviate significantly from the normal. The range of dentofacial deformity extends from gross facial disproportions that involve cranial and facial structures to those with severe dental malocclusions requiring orthognathic surgery. There is a degree of overlap between the upper end of the scale of dentofacial deformity and the milder forms of craniofacial deformity (Proffit and White, 1991). An anomaly requires treatment if the disfigurement or functional problem is likely to be a barrier to the patient's physical or emotional well-being (WHO 1962).

1.2.1 Incidence of dentofacial deformity

The National Health and Nutrition Examination Survey (NHANES III) in the USA reported approximately 20% of the US population to have deviations from the ideal occlusion, with 2% of these severe enough to be disfiguring and at the limit of orthodontic correction (Proffit *et al.*, 1998). The exact incidence of dentofacial deformities requiring orthognathic surgery is difficult to estimate because it includes a broad population of patients with deformities of congenital, developmental and traumatic origin. However, the number of individuals with developmental dentofacial deformities in the United States who may benefit from orthognathic surgery is estimated at 1.5-2 million; of these, approximately 1 million present with Class II deformities and 0.5 million with Class III deformities (Proffit *et al.*, 1998). It has been

estimated that up to 250,000 people in the United Kingdom have malocclusions severe enough to require orthognathic surgery (Kumar *et al.*, 2008).

1.2.2 Treatment need of dentofacial deformity

Problems associated with dentofacial deformities can affect oral function resulting in difficulties with speech, swallowing, mastication and occlusal trauma (Relle *et al.*, 2004). Facial disfigurement and deformity is associated with negative social and psychological effects (Philips *et al.*, 1998; Broder *et al.*, 2000, Cunningham, 1999; Macgregor, 1970; Macgregor, 1990). The psychological aspects of facial deformity should not be underestimated, daily social interactions for those with facial anomalies is a source of unrelenting stress, anxiety and anguish, all of which have implications for personality functioning and mental health (Macgregor, 1990). Individuals often have to endure negative social reactions from other members of the public ranging from stares and whispers to ridicule and alienation, with the result that they are socially disadvantaged and can be psychologically damaged. As a result one of the most common responses of individuals with facial disfigurement is to withdraw from social interaction (Neale *et al.*, 1986). Facial deformity and disfigurement is often associated with an altered self-image, and decreased self-esteem (Williams *et al.*, 1991).

Dentofacial disharmony negatively impacts on a patient's quality of life (Broder *et al.*, 2000). Those with a dentofacial deformity are more likely to have difficulty in everyday social situations and personal relationships (Rivera *et al.*, 2000). It has been reported that between one third and one half of all patients referred for treatment consultation had high levels of psychological distress to the extent that their overall quality of life was significantly affected

(Philips *et al.*, 1998). A recent study investigated the effects of facial disfigurement on psychosocial aspects of those born with craniofacial disfigurements (Sarwer *et al.*, 1999). Using a control group matched for age, gender and size, 24 facially disfigured adults were questioned about body image dissatisfaction, self-esteem, quality of life and experiences of discrimination. The craniofacially disfigured adults experienced greater dissatisfaction with facial appearance and significantly lower self-esteem and quality of life compared to the non-facially disfigured control group. Dissatisfaction with facial appearance, self-esteem and quality of life was related to self-ratings of physical attractiveness. More than one-third of those with a craniofacial anomaly reported experiences of discrimination in employment and in social settings because of their facial appearance. This study however had a small sample size and so the results should be interpreted with caution.

According to Macgregor (1970), the reactions of those who see someone with a deformed face range from compassion to repulsion. Often those with milder deformities are ridiculed and teased, while those with more severe facial deformities are treated with compassion (Macgregor, 1970). Individuals with milder anomalies are often more psychologically and emotionally distressed, as they tend to be subjected to unpredictable reactions from the public due to their facial appearance such that they are socially prejudiced (Macgregor, 1981; Cunningham, 1999). Sarwer *et al.* (1999) supported this view and found that there was not a linear relationship between the degree of the deformity and dissatisfaction with facial appearance, self-esteem and quality of life. While many of the facially disfigured samples reported severe dissatisfaction with facial aesthetics and low self-esteem compared to the control group, others detailed relatively little dissatisfaction with their appearance, self-esteem and quality of life. This may go some way to explain why a mild deformity can be more challenging to bear than a more severe anomaly.

1.2.3 Why patients seek treatment

Successful orthognathic surgery requires a combination of optimal tooth and jaw movements and an understanding on the clinician's part to fully assess the patient's motivations, concerns and expectations thereby ensuring a successful result (Proffit and White, 1991).

Two types of motivation have been described; some patients are motivated by a desire to change their appearance to please others, "external motivation" (Edgerton and Knorr, 1971). These individuals believe that their physical appearance is negatively impacting on their employment or on their social status. It has been suggested that patients in this category need to alter their personal environment rather than resorting to surgery to solve their problems (Cunningham, 1999). "Internal motivation" is when a person feels that their appearance is negatively impacting on their quality of life. Patients in this category are more likely to be satisfied with the treatment outcome (Cunningham, 1999). It is also worth noting that patients who had realistic expectations are more likely to be satisfied in the long term (Chen *et al.*, 2002). Therefore, it is of paramount importance that clinicians understand patients' motivation for and expectations of surgery before embarking on treatment (Nurminen *et al.*, 1999).

Modern society places increased importance on physical attractiveness (Macgregor 1981; Umberson *et al.*, 1987). The face has a profound social significance and it is a primary means of identification and a rich source of nonverbal communication (Cunningham *et al.*, 1995; Cunningham, 1999; Macgregor 1990). Macgregor (1990) suggests that such is the importance of facial aesthetics in modern society that if one's facial appearance is unattractive or disfigured this is effectively an index of their personal worth in society such that facial

aesthetics become more important than actual personal characteristics and qualities. Physical attractiveness is very important to people across all cultures and ages throughout the world, and those who request treatment are motivated by a desire to improve facial aesthetics (Kiyak *et al.*, 1988).

The increasing obsession with physical attractiveness often fuelled by unrealistic pictures of perfection in the media has in turn influenced the public's perception of what is an acceptable level of physical attractiveness. As a result, patients with facial anomalies can be distressed due to the images populated in the media, as there is pressure within modern cosmopolitan society to conform to an idealised appearance (McGrouther, 1996).

Studies have assessed the motivations of those who seek orthognathic surgery, and appearance is the major concern for many people seeking treatment (Jacobson, 1984; Flanary *et al.*, 1985; Kiyak *et al.*, 1998; Finlay *et al.*, 1995; Espeland *et al.*, 2008). Functional improvement is also considered an important factor as reported by a number of researchers (Jacobson, 1984; Flanary *et al.*, 1985). Most often, however, patients present with both functional and aesthetic concerns and it is the proportional importance of these factors that varies. Different social, psychological and cultural pressures motivate people to seek treatment to improve their facial appearance (Macgregor, 1981; Jensen, 1978). Eighty percent of adults requesting orthodontic treatment for themselves or their children are motivated by a desire to improve aesthetics regardless of structural or functional considerations, rather than health or function (Baldwin, 1980).

Studies have shown that most patients who request orthognathic surgery are motivated by an improvement in facial or dental appearance and not due to concerns regarding occlusal

function. Rivera *et al.* (2000) investigated patient's own reasons for undergoing orthognathic surgery and reported that improvement in physical appearance was a motivation given by 71% of the sample while improvement in function was a reason for 47% of the sample. Young and old, male and female were equally likely to express greater desires for an improvement in aesthetics (Rivera *et al.*, 2000).

According to Lee *et al.* (2007), patients seek orthognathic surgery to correct a dentofacial deformity, thereby improving functional ability, their body image, quality of life and social acceptability. The authors investigated the motivation of 74 female patients seeking orthognathic treatment to correct a dentofacial deformity. They found that these patients scored significantly lower than a control group for the following factors: perception of appearance, stigma of surgery and quality of life. This indicates that patients with dentofacial anomalies have a lower self perception of their appearance, and their body image negatively impacts on their psychosocial functioning and wellbeing in everyday life. Patients were more likely to "accept" corrective surgery and had higher scores in relation to stigma of deformity and appearance orientation. Appearance orientation refers to the psychological importance an individual places on their appearance. Patients' scores in relation to stigma of deformity revealed a significant negative impact due to dentofacial anomaly such that they felt socially disadvantaged with respect to: lack of popularity, devaluation in ability, problems making friends of the opposite sex, less chance of marriage and more easily insulted. Three factors were reported that were significant in predicting patient's motivations for seeking orthognathic surgery to correct a dentofacial deformity including: appearance orientation, stigma of surgery and the degree to which an individual is satisfied with their facial appearance.

1.2.4 Benefits of orthognathic surgery

Benefits of orthognathic surgery have been reported as improved self esteem, better body image and social acceptability (Rivera *et al.*, 2000; Hunt *et al.*, 2001). Patients are reported to generally experience functional and psychosocial improvements following orthognathic surgery (Pahkala and Kellokoski, 2007). Others have reported that following orthognathic surgery, an improved appearance is associated with psychosocial benefits (Lazaridou-Terzoudi *et al.*, 2003).

A recent systematic review investigated the psychosocial benefits of orthognathic surgery (Hunt *et al.*, 2001). The review found that almost all research indicated that orthognathic surgery did have psychosocial benefits. These included improvements in self-esteem, self-confidence, body and facial image, personality, emotional stability, mood and social adjustment. Not only did personal characteristics improve, in addition studies reported both improved personal relationships and employment opportunities. Post-orthognathic treatment patients were found to be less anxious and less-self conscious. The levels of scientific evidence to support these conclusions were not strong, and as a result the authors advise caution in interpreting the findings.

Patients should be offered the appropriate treatment to correct a disfigurement if it is subjectively perceived by them as a handicap, in part to improve the psychological outcome. Improvements in facial appearance, chewing ability and temporomandibular joint pain have been subjectively reported following orthognathic surgery (Pahkala and Kellokoski, 2007). However, in 12% of the patients, temporomandibular joint problems were worse after

treatment. The study concluded that patients who undergo orthognathic surgery experience functional and psychosocial benefits after surgical-orthodontic treatment.

1.3 Facial Attractiveness

1.3.1 Definition of beauty

Beauty has been defined as a quality which is enjoyed by the senses and the mind (Hilhorst, 2002; Naini, 2006). Facial beauty is a mystery, a complex concept for which there is no equation, set of absolute rules or numbers that can successfully describe it (Adamson *et al.*, 2006; Peck and Peck, 1970). Facial beauty is easier to recognise than to understand (Baig, 2004). Scholars and scientists from time immemorial have studied and attempted to understand and explain this complex multifaceted concept (Barker and Barker, 2002).

1.3.2 Difference between beauty and attractiveness

There is an important but subtle difference between facial beauty and facial attractiveness, and researchers have agreed that these terms may not always be interchangeable. Rhee and Koo, (2007) stated that facial beauty is not a rigid concept with hard and fast rules, but can evolve and change according to time, generation, age, gender, racial and ethnicity. On the other hand, facial attractiveness can be objectively measured and is defined as the “time-static visual properties of a face in a photographic two-dimensional frontal repose image that are pleasing to the visual sense of an observer” (Bashour, 2006b).

1.3.3 History of attractiveness and proportions

Throughout the ages artists, philosophers and scientists have debated the concept of facial attractiveness and attempted to decipher its components. From ancient Roman, Egyptian and Greek times through to the Renaissance, the concept of facial attractiveness has been studied and recorded in sculptures and paintings (Vegter *et al.*, 2000; Naini, 2008).

Each period of history shared a common ideal of aesthetic proportions. The Greeks elucidated “phi” the golden proportion which has been identified as an aesthetic ideal. Phi is the ratio obtained when a line ABC is cut such that AB/AC equals BC/AB . The ratio of the shorter section to the longer section of the line is equal to the ratio of the longer section to the entire line. This results in a value of 0.618 for AC/AB . Another proportion called the golden section is defined as the division of a line such that the ratio of the longer to the shorter segment is 1.618:1. These ratios are still used as a guiding principle by surgeons, architects and artists (Davis *et al.*, 1991). Leonardo da Vinci was fascinated by the concept of ideal facial proportions and produced drawings investigating different facial proportions (Vegter *et al.*, 2000; Naini, 2008).

The neoclassical “canons” or principles of proportion which originated from the Greeks, divide the face in to aesthetic proportions and are used as a guiding standard of aesthetics in many subjects (Bashour, 2006a). Many aspects of classic anthropometry still prove useful in modern anthropometry including the golden proportion which is used in the assessment of dentofacial aesthetics and in assessment of mesiodistal widths of the anterior teeth, even though there is little sound evidence to support it (Farkas *et al.*, 1985).

Objective systems such as the anthropometric system and the cephalometric system are recommended as the neoclassical principles are not thought to be a suitable guide for analyzing facial aesthetics (Bashour, 2006a). Vegter *et al.* (2000) suggest that modern anthropometry uses lie mainly in medical and forensic application, enabling the assessment of deformities and growth. It enables a more objective method for planning and assessing orthognathic treatment and maxillofacial surgery.

1.3.4 Basis of facial aesthetics

There is a general consensus that beauty has an evolutionary basis, ensuring the Darwinian survival of the fittest of the species (Sarwer *et al.*, 2003; Thornhill and Gangestad, 1999). It has been suggested that individuals judge facial attractiveness as a means of assessing features and interpreting visual cues that may indicate the health of another individual and their potential quality for mate selection (Thornhill and Gangestad, 1999). There is evidence to suggest that perception of beauty has a genetic basis. Rubenstein *et al.* (1999) found that even at 6 months old infants show a preference for attractive faces. It was reasoned that 6 months old is too early in human development for social influences from parents, peers and the media to take hold and conclude that the reason infants prefer an attractive face is due to the way our brains are wired, so called “general information processing mechanisms”.

1.3.5 Components of attractiveness

Researchers have long debated what constitutes attractiveness (Iliffe, 1960; Peck and Peck, 1970). It has been reported that there may be an intrinsic feature common to all beautiful

things and that beautiful faces may display varying amounts of this feature whether it is balance or harmony (Iliffe, 1960).

There are several factors that encompass attractiveness, including personality, personal appearance, physical looks and artistic looks which take account of choice of clothes, perfume and hair. In addition how an individual behaves, the manner in which they relate to and communicate with others, as well their ability to make friends is suggested to contribute to an individual's attractiveness. Society assesses individuals on these features and if lacking in physical beauty, corrective surgery is often the only solution to achieve physical attractiveness (Hilhorst, 2002).

The components of attractiveness have been investigated and include facial beauty, body attractiveness, attractiveness associated with a sense of dress, and dynamic expressive style including expressiveness, social and communication skills. On first encounters, facial attractiveness and expressive behaviour was reported to have the most influence on perception of attractiveness, whilst body attractiveness and attractiveness of dress had little influence on overall initial judgments of attractiveness (Riggio *et al.*, 1991).

There are different facial features which are believed to be assessed subconsciously, when judging facial attractiveness and aesthetics.

1. Averageness, average facial configurations are attractive.
2. Sexual dimorphism secondary to sex hormones.
3. Youthfulness and neoteny of the face.
4. Symmetry.

Bashour, (2006b) states that “facial attractiveness is attributable to both configurational (prototypicality, symmetry, and youthfulness) and featural cues (sexually dimorphic features)”. This is supported by Sarwer *et al.* (2003) who found that the physical components of beauty are facial and body symmetry, averageness of appearance, body size ratios and youthfulness. These features are important in mate selection and therefore have an evolutionary function.

There appears to be universal standards of human beauty; namely youth, symmetry and averageness of appearance. Researchers have long debated what constitutes an attractive face. Langlois *et al.* (1990, 1994) reported that composite images of the face made up of average features were rated as being more attractive than the actual face from which they were created. These findings were supported by Rhodes *et al.* (2001) who found evidence to support the concept that facial attractiveness was related to facial symmetry and average facial characteristics (Thornhill and Gangestad, 1999). Other researchers (DeBruine *et al.*, 2007; Perrett *et al.*, 1994; Alley *et al.*, 1991) found that attractiveness is not completely determined by average facial features, but that there are some non-average characteristics that are attractive. It has been suggested that an average facial configuration is not necessarily the critical determinant of facial attractiveness and that highly attractive faces can deviate systematically from the average (Perrett *et al.*, 1994).

Youthfulness is associated with attractiveness (Sarwer, 2003) and is perceived as being more attractive than older faces (Mathes *et al.*, 1985). Neoteny is associated with babyish features e.g. large eyes, small nose, round cheeks and smooth skin. Studies have shown that neotenous features are thought to be attractive (Cunningham, 1999).

An association has been reported between facial symmetry and ratings of attractiveness (Fink *et al.*, 2006). More symmetrical faces were perceived as being more attractive and these individuals were considered to be more sociable, intelligent, balanced and self-confident, while those with faces that were less symmetrical were perceived as being more anxious. Symmetry is thought to be a reflection of the quality of one's genes, such that the greater the facial symmetry the greater the ability of one's genes to create a symmetrical individual. A high sex-specific hormone load is thought to reflect a good immune system, hence the evolutionary association between sexual dimorphism (secondary to sex hormones) and facial attractiveness (Weeden and Sabini, 2005). This was assessed further in a study which asked females to rate the attractiveness and symmetry of black and white photographs of forty men's faces. They found two predictors of male attractiveness other than symmetry, namely a longer lower face and prominent cheek bones (Scheib *et al.*, 1999).

In conclusion, the literature would suggest that although average faces are attractive, many attractive features are non-average, but that faces whose facial features deviate to extremes are perceived as being unattractive.

1.3.6 Culture and beauty

There is a general consensus amongst researchers that not only does the general public agree in its judgment of facial aesthetics but that there is a cross-cultural agreement when assessing physical attractiveness (Iliffe, 1960; Martin, 1964; Perrett *et al.*, 1994).

The relationship between racial group and judgment of facial aesthetics was investigated (Martin, 1964). The study reported that the aesthetic judgments of white and black Americans

correlated highly, and it concluded that the different racial groups shared a similar standard when judging female facial aesthetics, which was found to be the Caucasian facial model.

Iliffe, (1960) investigated the preference for female facial aesthetics. Twelve black and white photographs of female faces taken in uniform conditions, aged 20 to 25, and chosen as being representative of different facial types were published in a national daily newspaper. In total 4355 readers responded to the request to judge the “prettiness” of the women’s faces. The author concludes that there was wide agreement amongst the population as to what was an attractive face.

Profile preference among different groups within the population has been assessed, including orthodontists, general dentists, art students, lay people, Chinese, black and white lay groups (Foster, 1973). They were shown silhouetted facial profiles with varying amounts of lip protrusion and asked to choose their profile preference. The groups shared a common aesthetic standard with respect to lip posture.

1.3.7 Social implications and importance of facial aesthetics

The face is our most noticeable feature and has a unique influence on how we perceive attractiveness in others and how we identify one another (Riggio *et al.*, 1991). Facial appearance is the focus of attention in social interaction as it gives us information on which we form first impressions of other people and without further interaction is the basis on how we judge others (Cunningham, 1999). Decades of research confirm the importance of physical attractiveness in our perception of others (Dion, 1972; Riggio *et al.*, 1991).

Attractiveness is a visual cue that people use to make assumptions and conclusions about the personality and behavior of others in once-off encounters and it can influence how we treat other. In modern society, physical beauty is perceived as a personal characteristic and is valued as such in its own right, independent of other traits (Hilhorst, 2002).

1.3.8 Associations of Attractiveness

The general consensus is that facial attractiveness does impact upon how others perceive individuals, such that attractive individuals are associated with more positive social attributes and characteristics (Dion *et al.*, 1972; Dion 1972; Walster *et al.*, 1966; Shaw, 1981; Shaw *et al.*, 1985; Cunningham *et al.*, 1999).

Dion *et al.* (1972) designed an experiment to test the hypothesis first proposed by the Greek philosopher Sappho who said “what is good is beautiful”. 60 college students (30 male, 30 female) were asked to look at head and shoulder photographs of young men and women who were categorised as “good-looking”, “average-looking” and “unattractive” by another group of raters. The college students were asked to rate the photographs on a variety of personal characteristics. The authors found that physically attractive people were considered to have more socially desirable personalities than unattractive individuals. The individuals within the “good-looking” group were seen as friendlier, warmer, kinder and stronger as well as being more stable, sincere, sensitive, exciting, interesting, modest, sociable and outgoing, compared to the average and unattractive groups. Good-looking individuals were expected to have better jobs, more successful marriages and in general, to experience happier and more fulfilling lives.

The influence of physical attractiveness and peer perception was examined in a group of young children (Dion, 1972). The study found that attractive and unattractive children were associated with different social behaviours such that unattractive children were associated with having more antisocial behaviour compared to attractive children. Levels of popularity increased for attractive female children in the older children while the popularity of unattractive female children declined in the older age group. Attractive children were associated with positive social attributes and perceived as more self sufficient and independent than unattractive children. These findings indicate that physical attractiveness does influence peer perception in very young children and according to the authors, it is a significant personal characteristic at a very young age.

It appears from the literature that society judges an individual's personal characteristics from their outward appearance at a very young age. An individual's physical appearance is associated with their inward character so that what is beautiful on the outside is also perceived to be beautiful on the inside. The "beautiful equals good" stereotype prevails.

1.3.9 Summary

There is a wide range of factors that may contribute to facial attractiveness such as symmetry, averageness, youthfulness and perhaps also something that is elusive and indefinable but intuitive to the human eye. However it is interesting to note that it is the distinguishing factors that also contribute to extraordinary beauty. Facial attractiveness is also greatly influenced by fluctuations in fashion and is very media-driven. Although there appears to be a universal agreement over the standard of facial beauty, the debate rages on over what it is exactly that constitutes facial attractiveness.

1.4 Objective Evaluation of Facial Attractiveness

1.4.1 Use of photographs for facial measurements

At present the main method of recording soft tissue appearance is in the form of photographs. Photographs are a non-invasive procedure enabling repeated capture (Strauss, 1997; Ferrario, 1993). Photographs provide an excellent two dimensional and marginally adequate three dimensional representation of the patient (Strauss, 1997). Other factors such as speed, convenience, quality and cost have been associated with digital photographs (Nechala *et al.*, 1999; Ferrario, 1993). While digital photographs are a permanent record, they can also be used to provide a high quality hard copy of the image at a later date if required (Nechala *et al.*, 1999).

Photographs are a two dimensional representation of a three dimensional object and the image can be influenced by patient posture, muscle tone, fatigue, the mood of the patient and the time of the day at which the photograph was taken (Strauss, 1997). The photographic image lacks some of the finer details that can be assessed during a clinical examination including information on facial dynamics (Strauss, 1997) and are not a replacement for a live subject (Farkas, 1994).

According to Farkas, (1994) photogrammetry of the face is also known as indirect anthropometry and is “anthropometry adapted for quantification of surface features from standard photographs.” Photogrammetry involves recording measurements of facial landmarks from standard photographs; as opposed to anthropometry where the measurements are taken from the subject’s face. By using a standard photographic technique,

photogrammetry provides an accurate and scientific method of recording facial measurements (Farkas, 1994).

An advantage of photogrammetry compared to anthropometry is that the time taken to identify landmarks directly on the patient is greatly reduced, and this can be of great benefit in those subjects that are less compliant e.g. young children (Farkas, 1994). Anthropometry involves the direct measurements of structures including soft and hard tissue of the face. Differences in pressure when measuring soft tissue landmarks can also occur with different clinicians and can result in inaccurate measurements. Certain landmarks are more suitable for indirect measurement e.g. soft tissue landmarks around the eye as this may be uncomfortable for the patient (Douglas, 2004).

1.4.2 Standardisation of photographs

The use of standardised techniques allows the consistent comparison of photographic images of a patient. This is important when measurements are taken from photographs (Farkas, 1994; Claman, 1990). In order for photographs to be of value, they must be taken using a standardised technique (Arnett and McLaughlin, 2004; Strauss, 1997; Gordon and Wander, 1987; Farkas, 1980).

The use of a standardised photographic technique enables the qualitative analysis of craniofacial soft tissue measurements (Ferrario, 1993). Standardising photographs reduces the inter-subject variability in taking the same measurements on different patients (Strauss, 1997). Standard photographic conditions enable direct comparison between photographs, even if the photographs are taken at different time periods and by different photographers. Photographs

should be as reproducible as possible, and the conditions in which they are taken should be reproducible, including the photographic equipment, lighting, scale of reproduction and the framing of the photograph (Bengel, 1985). A standardised photographic technique involves correct and consistent positioning of the subject for each photograph, with the same instructions to all subjects under standard photographic conditions (Bengel, 1985; Arnett and McLaughlin, 2004).

1.4.3 Photographic reproducibility

Whilst photographs are a useful tool there is some variability between photographs even when using a standardised technique (Stephan *et al.*, 2004). When standardisation is not fully achieved, there is a greater variation between the photographs, and significant errors are likely.

Strauss, (1997) investigated the reproducibility of facial photographs and the effect this may have on facial measurements over time. The aim of the study was to determine whether facial photos are reproducible to an acceptable level when treatment planning for orthodontic or orthognathic surgery. The study involved 20 subjects attending 5 photo sessions over a 7 to 14 day period, with a minimum of 24 hours between each session. Full frontal, frontal smiling, full-lateral and close up facial views were taken using a standardised photographic technique. The subjects photographs were repeated and 18 measurements of the photographs were recorded. The accepted clinical margin for reproducibility was set at 1mm for linear measurements and 2 degrees for angular measurements. The results indicate that the least accurate measurements were from smile photographs and lower lip length measurement. The overall mean accuracy for all measurements was 79.1%; however significant variability was seen in some patients.

1.4.4 Photographic validity

In an attempt to determine the validity of photographs, Farkas, (1980) compared facial measurements obtained by direct anthropometry against measurements taken from standardised photographs of the same subject. The study involved 36 healthy young white Canadians, 18 male and 18 female subjects. Standard landmarks used in anthropometry were marked on the skin of the subject's faces and a total of 64 measurements were used for comparison. Linear measurements from the photographs were recorded using a sliding calliper and angular measurements were taken with a protractor. Measurement reliability was determined according to the average difference between the indirect and the direct measurements, which if found to be greater than 1mm or 2 degrees were regarded as inaccurate. Overall the study found 20 of the 62 measurements were reliable. Lateral profile views were associated with the most valid measurements (13 out of 20 measurements) compared to frontal prints which had a total of 10 reliable measurements.

1.4.5 Sources of errors in photogrammetry – identification of soft tissue landmarks

Farkas, (1994) cited the following factors which can affect landmark identification;

- Landmarks covered by hair or hidden behind facial features, e.g. on profile photographic views porion can be hidden behind tragus, or the commissure of the labial fissure may be concealed by skin crease.
- Certain landmarks cannot be viewed, e.g. glabella cannot be seen if hidden by an eyebrow and trichion can be concealed by hair.

- Some landmarks cannot be marked, e.g. inner and outer commissures of the eyes and mouth, while others may not be clearly visible on the photograph to be measured, e.g. the most lateral point of the ala.
- Landmarks that are on the edge or contour of anatomical features can be difficult to identify.

1.4.6. Sources of errors in photogrammetry – subject positioning

The subject's head position can influence measurements such that when taking a profile photograph if the head is tilted forward the subject appears to have a recessive chin and if the head is tilted backwards, can appear to have a prognathic mandible (Strauss, 1997; Farkas, 1980). Errors occur when the subject's face is incorrectly positioned such that the profile line in the photograph is not a true reflection subject's facial profile (Farkas, 1994).

Farkas, (1980) recommends proper positioning of the subject's head with respect to the vertical and horizontal planes, suggesting that markers on the face can enable the Frankfurt horizontal to be located. Using the Frankfurt horizontal to position the subject's head may not be ideal as it can be uncomfortable and unnatural. The rest position also known as natural head position which is approximately 5 degrees above the Frankfurt horizontal is preferred (Farkas, 1980). Natural head position (NHP) has been defined as "the position adopted by the head when the subject is sitting or standing in a relaxed upright position" and has been described as "a standardised orientation of the head with the eyes focused on a distant point" (Lundstrom *et al.*, 1992). NHP involves the use of an extra cranial reference line for orientation and this technique provides a reproducible true horizontal reference line that can be used in clinical, photographic and radiographic assessment (Luyk *et al.*, 1986). Use of the Frankfort plane to

orientate the subject's head has been recommended by a small number of studies (Claman *et al.*, 1990; Sommer and Mendelsohn, 2004) while the majority favour the use of natural head position (Philips *et al.*, 1984; Benson and Richmond, 1997; Cooke, 1990).

NHP has been used extensively in the orthodontic literature when analysing craniofacial morphology as it is the logical reference and orientation position for the evaluation of craniofacial morphology (Moorrees and Kean, 1958; Solow and Tallgren, 1971; Lundstrom and Lundstrom, 1992; Lundstrom *et al.*, 1995; Leitao *et al.*, 2000; Cooke and Wei, 1988).

1.4.7 Sources of errors in photogrammetry – photographic distortion

Photographs are a two dimensional representation of a three dimensional object and are subject to errors of projection which result in distortion and differential magnification due to the effect of the camera lens. Photographic distortion occurs when the camera is focused taking a profile photograph, due to the three dimensional nature of the face, certain parts will be more in focus than others resulting in distortion and inaccuracies when measuring two landmarks that have different field depths (Farkas, 1994; Douglas, 2004).

1.4.8 Summary

The use of photographs to capture the face in two dimensional (2D) remains the main method of carrying out indirect anthropometry despite the more widespread use of three dimensional (3D) techniques (Nechala *et al.*, 1999). While more sophisticated 3D techniques do have additional benefits compared to 2D techniques, 2D remains a popular and widespread technique employed by clinicians. This is due to cost, accessibility, portability and ease of use

of conventional equipment i.e. a digital camera. Few centres have the expertise and financial resources to harness the use of 3D imaging. Computer packages used in the planning of orthognathic surgery are still mainly based on profile views of patients. It is therefore not within the scope of the review to address the area of 3D imaging.

1.5 Previous Studies Analysing Soft Tissue Profile

Several studies have attempted to objectively measure facial “norms” based on angular and linear measurements of profile photographs in relationship to a true vertical line (Arnett *et al.*, 1999; Fernández-Riveiro *et al.*, 2002; Fernández-Riveiro *et al.*, 2003; Anicÿ-Milosevicÿ *et al.*, 2008a; Anicÿ-Milosevicÿ *et al.*, 2008b; Scavone *et al.*, 2008; Kale-Varlk *et al.*, 2008; Malkoç *et al.*, 2009; Uysal *et al.*, 2009). A summary comparing the studies that have analysed soft tissue profile is found in Table 1.1.

1.5.1. Age

The ages of the samples studied were broadly similar, which varied from 18 to 40 years, with most studies sampling adults from the ages of 18 to 30 years. The widest age range was 21 to 40 years (Kale-Varlk *et al.*, 2008). However, as the population samples were young and early middle-aged adults who had completed growth, comparison between most of the studies is possible. However, the study of Arnett *et al.* (1999) studied a sample of adults, but the mean age and range of ages was not reported.

1.5.2 Inclusion criteria

All similar studies specified that only those individuals with a Class I occlusion or normal occlusion were eligible for inclusion (Arnett *et al.*, 1999; Anicÿ-Milosevicÿ *et al.*, 2008a;

Anić-Milosević *et al.*, 2008b; Scavone *et al.*, 2008; Kale-Varlık *et al.*, 2008; Malkoç *et al.*, 2009; Uysal *et al.*, 2009). This was presumably on the assumption that Class I occlusion is indicative of a Class I skeletal base, but this may be incorrect due to dental compensations of underlying skeletal problems.

Several studies attempted to address this issue by subjectively assessing facial profile (Arnett *et al.*, 1999; Anić-Milosević *et al.*, 2008a; Anić-Milosević *et al.*, 2008b; Scavone *et al.*, 2008) and only including subjects with balanced faces or pleasing profiles. A sample of Caucasian American models with a Class I occlusion were selected for soft tissue cephalometric analysis with the aim of quantifying good facial harmony (Arnett *et al.*, 1999). Inclusion selection was based upon the very subjective assessment of “good facial balance” by one expert individual. Also, the potential of selection bias exists, as selection of the trial sample was carried out by the three authors of the paper.

1.5.3 Differences in methods used

- Records used to analyse facial appearance

Differences exist between studies with regard to the type of record taken; some studies took measurements from cephalograms (Arnett *et al.*, 1999; Uysal *et al.*, 2009) while all remaining studies used photographs.

- Method used when taking the record

Studies differed with respect to jaw position when taking records. This could affect the soft tissue profile and affect the results making direct comparison difficult. Jaw relationship differed between studies, with some employing centric occlusion (Kale-Varlık *et al.*, 2008),

Table 1.1 Details of previous studies on lateral facial soft tissue measurements (continued on next page)

	Arnett <i>et al.</i> (1999)	Fernández-Riveiro <i>et al.</i> (2002; 2003)	Anić-Milosević <i>et al.</i> (2008a; 2008b)	Scavone <i>et al.</i>, (2008)
Males	20	50 (Linear study) 67 (Angular study)	52	30
Females	26	162 (Linear study) 208 (Angular study)	58	29
Ethnicity	White American	White Galician	Caucasian Croatian	White Brazilians
Age (years)	Adult	18-20	23-28	18-30
Inclusion criteria	Models. Class I occlusion. Facial balance. Selected by a single individual.	No craniofacial anomalies. Random selection of medical and dental students. Not necessary Class I skeletal patterns – includes all skeletal types.	Class I occlusion. Minimal spacing and crowding. Balanced and pleasing profile as selected by 2 expert individuals. Competent lips. No visual imbalances. No previous orthodontic or surgical treatment. Absence of major skeletal problems.	Normal occlusions. Orthognathic profile. No facial asymmetry. Lip seal. No previous orthodontic treatment, trauma or facial surgery. Selected by 2 Brazilian Orthodontists.
Records used	Standardised cephalograms.	Standardised photographs.	Standardised photographs.	Standardised photographs.
Methodology	Natural head position. Seated condyles. Passive lips.	Natural head position. Relaxed lip posture.	Natural head position.	Natural head position. Centric relation. Relaxed lip posture.
Measurements	Angular and linear	Angular and linear	Angular and linear	Angular and linear
Reference lines	True vertical through Subnasale	True vertical through Nasion True vertical parallel to True vertical through Nasion True horizontal perpendicular to True vertical through Tragus Canut line (Sn-B)	True vertical through Subnasale Canut line (Sn-B) Burstone line (Sn-Pog) Ricketts line (Prn-Pog)	True vertical through Subnasale

	Malkoç <i>et al.</i> (2009)	Uysal <i>et al.</i> (2009)	Kale-Varlık <i>et al.</i> (2008)
Males	46	67	47
Females	54	66	64
Ethnicity	Anatolian Turkish	Anatolian Turkish	Anatolian Turkish
Age (years)	19-25	Males 22.6 ± 2.2 Females 22.1 ± 2.6	21-40
Inclusion criteria	Turkish with Turkish grandparents. Random sample. Class I occlusion. Minor or no crowding. Normal growth and development. Well-aligned dental arches. All teeth present except third molars. Well balanced faces. Good facial symmetry. No significant medical history. No history of trauma. No previous orthodontic or prosthodontic treatment. No previous maxillofacial or plastic surgery.	Angle Class I occlusal relationship with normal overbite and overjet. Well-aligned upper and lower dental arches. Normal growth and development pattern. No history of previous orthodontic or prosthodontic treatment. Normal anteroposterior and vertical relationships as judged by the value of the ANB and SN-MP angle.	All grandparents of Anatolian origin. Skeletal Class I pattern. No facial asymmetry. Overjet that did not affect soft tissue profile.
Records used	Standardised photographs	Standardised cephalograms	Standardised photographs
Methodology	Natural head position. Relaxed lip position. Subject's forehead, neck and ears clearly visible.	Natural head position.	Natural head position. Centric occlusion. Lips at rest.
Measurements	Angular	Angular and linear	Angular
Reference lines	True vertical through Nasion True vertical parallel to True vertical through Nasion True horizontal perpendicular to True vertical through Tragus	True vertical through Subnasale Frankfort horizontal	No details given

centric relation (Scavone *et al.*, 2008) or a “seated condyles” position (Arnett *et al.*, 1999) while the remaining studies did not specify the jaw relationship.

- Reference lines with regard to the sample size used to orientate the image

Reference lines were used in order to take measurements from, the majority of studies used a True Vertical (TV) through subnasale (Arnett *et al.*, 1999; Scavone *et al.*, 2008; Anić-Milosević *et al.*, 2008b; Uysal *et al.*, 2009) while one study used a True Vertical line through nasion (Fernández-Riveiro *et al.*, 2002; Fernández-Riveiro *et al.*, 2003). The use of different reference lines results in different measurements such that the direct comparisons may not be made between these studies.

Summary

Although the studies may have some weaknesses and limitations in their methodology, nevertheless, the aims of the various studies were broadly similar; which was to measure 2D soft tissue profile values in samples of normal males and females. Currently, the normal values for various populations has been determined, however, there have been no studies carried out that have investigated the 2D soft tissue profile measurements in a trial sample recruited from the normal population in the West of Scotland. Additionally, no studies have been carried out that compare a sample of those who have undergone orthognathic surgery to a control population using 2D profile soft tissue measurements as an outcome measure.

1.6 Subjective Evaluation of Facial Attractiveness

Previous attempts to subjectively evaluate facial attractiveness have been based on a variety of scoring systems and panel assessments, in which rating or ranking by a group of professional or lay individuals or both is undertaken (Roberts-Harry, 1992; Peerlings *et al.*, 1995; Knight and Keith, 2005; Tatarunaite *et al.*, 2005; Shafiee *et al.*, 2008). Professional opinions regarding the assessment of facial aesthetics may not correspond with the perception and expectation of both patients and lay people (Albino *et al.*, 1984). The perception of facial aesthetics by professionals, non-professionals and patients has been found to differ (Shaw *et al.*, 1975; Albino *et al.*, 1984). However Tedesco *et al.* (1983a) found a moderately high level of inter-rater reliability and perception of dentofacial aesthetics between both orthodontists and lay judges.

1.6.1 Lay panel versus expert panel

Several factors related to panel composition have been reported to influence the rating of facial attractiveness including; gender, ethnicity, age, a professional versus a lay panel and the level of training and education of panel members. While high levels of correlation between professional and lay panels have been described (Peerlings *et al.*, 1995; Kiekens *et al.*, 2005), other studies have found a difference between professional and lay opinions regarding facial aesthetics (Albino *et al.*, 1984; Bell *et al.*, 1985; Kokich *et al.*, 1999). It is suggested that the level of training and experience of professionals influences their rating of facial appearance (Tedesco *et al.*, 1983; Prahl-Anderson *et al.*, 1979; Lines *et al.*, 1978; Philips *et al.*, 1992b; Cochrane *et al.*, 1997). Prahl-Anderson *et al.* (1979) investigated the differences in perception of dentofacial morphology among orthodontists, general dentists and parents of children

participating in the Nymegen Growth study. A total of 1,150 parents, 72 general dentists and 54 orthodontists were asked to subjectively assess the line drawings of facial profiles and colour photographs of dentitions. They answered questions as to the normality or abnormality of dentofacial appearance and the need for orthodontic treatment. Significant differences were found between the parents and the professionals, with the parents more accepting of dentofacial morphology that deviated from the normal and not requiring treatment. Lay people were less critical than general dentists and orthodontists regarding the aesthetics of photographs of the dentition. The study found no significant difference between the assessments of the orthodontists and the general dentists. The authors suggest the reason for the difference in evaluations and perceptions between the groups is due to the difference in knowledge and experience of each group. This was reiterated by Tedesco *et al.* (1983a) who suggested that the orthodontist's training influences their evaluation of facial aesthetics and recommended the use of lay panel members.

In a further study, Cochrane *et al.* (1997) assessed a lay panel and orthodontic panel's preference for skeletal profile and found a significant difference between the opinion of orthodontists and lay person regarding the most attractive profile. Orthodontists were 40 times more likely than lay persons to choose Class I skeletal profile as the most attractive. Both groups agreed on the most unattractive profile. The explanation for the difference between orthodontist and lay person opinion was that orthodontists tend to focus on different parts of the face, such as the mid-third or lower third, while patients tend to view their facial aesthetics as a whole. They suggest that lay persons are not trained to be as critical of facial aesthetics as orthodontists and will not be as familiar with viewing profile images.

Lines *et al.* (1978) found significant differences in assessment of facial profile between professionals, including orthodontists, oral surgeons, dentists and lay people. The results found that the opinion of those who were untrained in the assessment of facial aesthetics differed from orthodontists and oral surgeons, while orthodontists differed in their facial profile preference to oral surgeons. This suggests that different levels of training and experience influence the evaluation of facial appearance. The authors found a statistically significant difference between the evaluators preference for male and females profiles. A flaw of this study is that dentists, medical and dental students were categorised as not having training in facial aesthetics, however it is probable they will have a better understanding and more experience of appraising and analysing facial aesthetics than other non-professionals.

Lay people are more likely than general dentists, orthodontists or oral surgeons to assign normal ratings to profile drawings (Bell *et al.*, 1985). Oral surgeons and orthodontist evaluate facial profiles similarly; however surgeons are more likely to recommend surgical correction.

1.6.2 Effect of gender and race

Other variables that influence the assessment of facial attractiveness include gender; ethnicity and number of participants in the lay panel. Tedesco *et al.* (1983b) assessed the consistency of judgements of dentofacial attractiveness with regard to the gender and race of both the raters and those being assessed. The raters comprised of college freshmen, including equal numbers of black females, black males, white females and white males each of whom scored the photographs of the dentofacial aesthetics teenagers, including equal numbers of black and white females and black and white males. The authors found that female raters judged all photographs to be more attractive than male raters. Black raters judged all photographs to be

more attractive than white raters. There was no significant difference found for dentofacial attractiveness rating of black and white or male and female photographed children.

Flores-Mir *et al.* (2004) evaluated and compared the aesthetic perception by a lay panel consisting of 91 randomly selected adults, of smiles in different facial and dental views. They found that moderate correlations between the aesthetic ratings using a lay panel. Intra evaluator effects (level of education and age) did not consistently influence the aesthetic perception of smiles but gender did. They found the opposite of Tedesco *et al.* (1983b), in that males were consistently less critical than females evaluating the same photograph. They make a number of recommendations when using a lay panel, including larger and more significant sample of lay people in different socio cultural settings, and similarly to Tedesco *et al.* (1983b), supports the finding that differences in aesthetic perception exist according to ethnic origin. They advise a standardisation of socioeconomic status as well as cultural and religious status, for the lay panel and recommend homogeneity in racial origin in the photographed subjects, and that the lay panel should be selected from pure race origin if possible.

1.6.3 Panel number

The ideal number of panel members has been reported with a range of numbers recommended; from four (Peerlings *et al.*, 1995) to more than twelve (Tedesco *et al.*, 1983b). Howells and Shaw, (1985) found that a two person panel using photographs to rate facial attractiveness was valid, reliable and reproducible. Reliability could be further improved by increasing the panel size. A more recent study by Kiekens *et al.* (2007) found a randomly selected panel size of seven to be the ideal panel size.

1.6.4 Conclusion

According to Bell *et al.* (1985) and Kiyak *et al.* (1981), patients requesting orthognathic surgery are usually considered to be unhappy about their facial aesthetics; however they may not perceive their facial appearance in the same way as the oral surgeon and orthodontist.

Numerous studies have investigated how professional and lay panels perceive facial aesthetics, and have confirmed that the two groups view facial aesthetics differently (Albino *et al.*, 1984; Bell *et al.*, 1985; Kokich *et al.*, 1999). Prahl-Anderson *et al.*, (1979) and Kerr and O' Donnell, (1990), found that clinicians are more critical of dentofacial aesthetics than the general public. Kokich *et al.* (1999) found a fundamental difference in the perception of smile aesthetics between orthodontists, general dentists and lay people.

Lack of consensus has implications for success of treatment aims and goals. Many failures are not the result of technical difficulties but of differences between the clinician's goals and the patient's perception of their facial appearance and expectation of the treatment outcomes (Albino *et al.*, 1984). Many patients request orthodontic and orthognathic treatment to improve their facial aesthetics and become more attractive in the belief that it will result in other perceived benefits. Clinicians are trained to be critical; and provide the best aesthetic result as they perceive it. A mismatch between the clinician's and the patient's perception is not conducive to a successful result.

From the literature, it is evident that the dental professional has a different perception of facial aesthetics, and dentofacial morphology to that of lay people. In recommending treatment to

patients, it is important for orthodontists and oral surgeons to know whether their evaluation of facial aesthetics is similar to the general public.

1.7 Use of the Visual Analogue Scale (VAS)

A Visual Analogue Scale (VAS) is a simple method that has been used to measure subjective experiences and behaviours and has been reported to be valid, reliable and sufficiently sensitive for use in clinical and research topics. It is one of the most frequently used measurement scales in health care research and is easily constructed, simple to use and is a quick method of scoring making it a practical tool for use in clinical situations (Wewers and Lowe, 1990; McCormack *et al.*, 1988).

The VAS was first developed by Hayes and Patterson in 1921 to rate employees work and further developed by Freyd in 1923 who used it to study personalities, finding it to be generally useful. More recently the VAS has been used to measure mood by Aitken and Zealley, (1970) and since then has been applied to many clinical and research topics such that it's use is now widespread (Ahearn, 1997; McCormack *et al.*, 1988).

A common method to assess facial and dentofacial attractiveness is to use panels of different types of raters to evaluate facial attractiveness (Lundstrom *et al.*, 1987; Todd *et al.*, 2005; Kiekens *et al.*, 2007). Different methods have been used for panel assessment of facial and dentofacial aesthetics, and can be divided in to two main groups. The first category includes rank order scales, whereby the results of an assessment are not separated by equal intervals, but are relative and organised ordinally which can affect the statistical analysis. The second category involves a visual analogue scale (VAS) which is in contrast to rank order scales, as

the scores are absolute and a rater's assessment score for each object is relatively independent from the others (Scabbel *et al.*, 2009). VASs have been used widely in studies assessing facial and dentofacial aesthetics (Philips *et al.*, 1992a; Kokich *et al.*, 1999; Faure *et al.*, 2002; Kiekens *et al.*, 2007).

The VAS represents a continuous range of values and consists of either a horizontal or vertical straight line with anchor terms at either end indicating the minimal and maximal extremes of the dimension under examination (Wewers and Lowe, 1990). In a horizontally orientated VAS, the higher end of the scale is to the right. In a vertically orientated VAS the higher end of the scale is towards the top, both can be used with or without graduated markings. A horizontal line is commonly used as it is associated with a more uniform distribution of scores compared to a vertical VAS which has been found to be associated with higher failure rates (Scott and Huskisson, 1979; Scott and Huskisson, 1976). This was due to the fact that some patients did not understand the concept. Other researchers (Gift, 1989) have recommended the use of the vertically orientated VAS, suggesting that the vertical scale was more sensitive, produced higher scores, and was easier for subjects to use than the horizontal scale. While the VAS may vary in orientation and anchors, it is valid (Gift, 1989). Good correlation has been found between vertical and horizontal when using the VAS, with the scores from the horizontal scales slightly lower than those from the vertical scales. It has been recommended that the same scale be used throughout a study (Scott and Huskisson, 1976).

Word descriptors at either end of the scale signify the maximum and minimum limit on the scale. Anchor terms used in studies on depression have included "most happy" and "most depressed", studies on pain using VAS have used the anchor terms "no pain" at one end and "pain as bad as it could possibly be" at the other end (Aitken and Zealley, 1970). Numbers

and verbal labels used as intermediate points can result in a clustering of scores around a preferred number (Aitken, 1969; Scott and Huskisson, 1976). Studies that have used VAS to assess dentofacial and facial aesthetics commonly used descriptor terms such as “very unattractive” to indicate zero and “very attractive” to indicate the opposite end of the scale (Philips *et al.*, 1992a; Philips *et al.*, 1992b; Howells and Shaw, 1985; Kokich *et al.*, 2006). Reproducibility of previous marks varies along the length of the VAS and subjects tend to estimate accurately along the extremes or in the centre of the line while the region 2 cm either side of the midpoint has been reported to be the least reproducible (Dixon & Bird, 1981).

The length of the line can vary but commonly tends to be 100 millimetres as one part in a hundred is adequately sensitive Aitken, (1969). Lines shorter than 100mm tend to produce greater error variance (Revill *et al.*, 1976). Studies assessing dentofacial aesthetics commonly used 100mm lines (Howells and Shaw, 1985; Philips *et al.*, 1992a; Philips *et al.*, 1992b) but longer and shorter lines have been used e.g.150mm and 50mm (Kokich *et al.*, 2006). The participant marks a position along the VAS line that is representative of their perception of a subjective experience under assessment. The VAS is scored by measuring the distance from the one end of the scale to the subject’s mark on the line.

The construction of a VAS has been described in a number of stages by Scott and Huskisson, (1976). Initially the sensation or response to be observed must be defined. Then the anchor terms are decided which indicate the maximum and minimum of the subjective experience under observation. These should be easily understood, short and not so extremely worded as to never be used. The line should have definite cut off points and be of an appropriate length. The VAS should be introduced to the participants with a standardised suitable question prior to the commencing the assessment.

The VAS has been used as method to rate subjective phenomena in research, and in medicine including mood (Zealley and Aitken, 1969), quality of life (Priestman and Baur, 1976), depressive illness (Zealley and Aitken, 1969). Subjective phenomena such as feelings and sensations are continuous and words do not always convey precisely how a person judges a subjective experience. Digital rating scales used to measure subjective phenomena can result in artificial categories. The VAS represents a continuous range of values and is a more sensitive rating scale than either verbal or digital rating scales (Aitken, 1969).

The VAS system has been applied widely in research as they are simple to employ and can be modified for use in a wide range of research settings. The scale has been found to be simple and quick to construct, quick and easy to apply and score, easily understood by subjects and appropriate to be used repeatedly and often (Ramplings and Williams, 1977). It is a very sensitive technique which is better able to discriminate than other types of scales (Scott and Huskisson, 1976), can be used by untrained staff (Morrison, 1983) and has been reported to have fewer limitations than other methods (Zealley and Aitken, 1969).

Some participants find it difficult to convert a subjective sensation to a straight line. Huskisson (1974) investigated the measurement of pain and found that having explained the VAS technique 7% of his subjects were unable to use it. This difficulty has been removed by teaching participants how to apply the technique and by ensuring the participants receive written instructions (Guyatt *et al.*, 1987).

Visual analogue scales do have limitations including a participant's interpretation of an anchor term which may be different to others (Aitken, 1969); however the careful choice of simple and concrete descriptors can reduce the likelihood of this happening. Accurate reproduction

of the scale is essential and photocopying has been found to distort the length of the scale. The angle at which the subject views the VAS may alter the placement of the mark especially when using a vertical line scale and it is recommended that a vertical VAS should be viewed from a vertical position (Dixon and Bird, 1981).

It is important to assess suitability of the VAS for the specific subject population before use since it can be treated differently by different populations. Mental disorganisation and confusion, loss of ability to think abstractly, effects of medication on comprehension, difficulties in understanding and with hand-eye coordination, loss of perceptual skills and memory which can occur in the elderly population can impede successful use of the VAS (Wewers and Lowe, 1990).

Summary

The VAS has been reported to be a valid and consistent method of measuring a range of subjective phenomena and behaviours with high levels of validity reported (Aitken, 1969; McCormack *et al.*, 1988). This method has been used for both comparisons between groups of subjects and for self subject comparison and significant levels of inter rater reliability have been reported. Participants have been found to be able to assess the same subjective or behavioural dimension at a similar point using this technique (McCormack *et al.*, 1988). Markings on VAS has been reported to reduce its sensitivity, while reliability is enhanced when stable phenomena are being evaluated (Gift, 1989). Patient compliance and insufficient explanation are reported to be the greatest sources of error associated with VAS (Dixon and Bird, 1981). Teaching should be provided prior to commencing the study or clear written instructions given (Gift, 1989; Ahearn, 1990).

Chapter Two

Rationale and Aims

2 Rationale and Aims of the Study

2.1 Rationale for the Study

Orthognathic surgery is becoming more widely available and acceptable as a treatment for facial anomalies and malocclusions as is indicated by the increasing demand (Jensen, 1978; Cunningham, 1999). Aesthetic improvement has been found to be the primary motivating factor for patients who seek orthognathic surgery (Kiyak *et al.*, 1981; Flanary *et al.*, 1985; Jacobson, 1984; Finlay *et al.*, 1995; Espeland *et al.*, 2008).

Current methods of assessing this aesthetic improvement of orthognathic surgery are based on subjective assessments by the clinician and patient; including patient questionnaires aimed at eliciting the patient's personal view of the outcome of the treatment (Pahkala and Kellokoski, 2007; Lazaridou-Terzoudi *et al.*, 2003). The perception of facial aesthetics by professionals has been found to differ from that of patients (Shaw *et al.*, 1975; Albino *et al.*, 1984). This would indicate that current methods based on subjective opinions are not adequate as individual bias influences the assessment of the results of treatment. There is a lack of research providing objective measures by which the results of orthognathic surgery can be assessed.

It is a patient's perception, as a lay person, of facial attractiveness that is paramount when assessing the outcome of surgery. Using a lay panel to select a group of attractive subjects would provide a control group with facial aesthetics that would be desired by a patient, a lay person themselves, and therefore a goal of treatment.

Assessment of facial aesthetics using two dimensional (2D) profile soft tissue facial measurements is a clearer, more consistent and standardised method than subjective assessment. In order to assess the success of treatment the post-operative orthognathic surgery patient's facial aesthetics can be compared to a control group of the population. There are currently no reference values for 2D soft tissue facial profile measurements for a West of Scotland population to which the 2D profile soft tissue measurements of post-operative orthognathic patients can be compared. This study provides a method by which objective measures in the form of angular and linear facial profile measurements can be used to assess the outcome of orthognathic surgery.

2.2 Aims of the Study

1. To determine the 2D soft tissue facial profile measurements of a control group of attractive individuals aged 18 to 35 years old, males and females from the West of Scotland as selected by a lay panel. The null hypothesis being that there is no difference in the angular and linear measurements between males and females.
2. To compare the 2D soft tissue facial profile measurements of a group of post-orthognathic surgery patients to a control group of attractive subjects. The null hypothesis being that there is no difference in the angular and linear measurements obtained from a group of post-orthognathic surgery patients and the control group of attractive subjects.

Chapter Three

Materials and Methods

3 Materials and Methods Part 1

3.1 Study Design

The overall aim of the study was to compare, using angular and linear measurements, the two-dimensional (2D) lateral facial appearance of a group of post-surgical orthognathic patients to a control group of attractive individuals. Ethical approval for the study was obtained from the Local Area Dental Ethics Committee of North Glasgow University Hospitals NHS Trust, Appendix I.

Part I of the study involved the selection of a control group of “attractive” individuals from a group of volunteers. A concurrent study recorded three dimensional (3D) facial images of the same group of volunteers by stereophotogrammetry. These images were then shown to a lay panel who rated the attractiveness of the individuals using a Visual Analogue Scale (VAS). The control group consisted of those individuals who were most consistently considered attractive by members of a lay panel.

3.2 Subjects

Subjects for the control group were recruited on a voluntary basis from within the local population of the West of Scotland. Subjects were recruited over a ten month period from April 2008 to January 2009.

3.2.1 Inclusion criteria

- Caucasian individuals from the West of Scotland.
- Both parents originating from the West of Scotland.
- Subjects to be aged between 18-35 years of age.
- Informed consent obtained to participate in the study.

3.2.2 Exclusion criteria

- Craniofacial defect or syndrome.
- Facial hair.
- Non-Caucasian origin.
- Not originating from the West of Scotland.
- Parents of subjects not originating from the West of Scotland.

3.3 Materials

3.3.1 The 2D imaging system

As well as capturing the subjects using 3D stereophotogrammetry, each subject was captured using a 2D system. The 2D imaging system (Figures 3.1, 3.2) consisted of a tripod (Bilora Stativ, model number 75-64, W.Germany) that held a 35 mm digital SLR camera (Fuji S2, Tokyo, Japan) with a 105 mm macro lens. Illumination of the subjects was achieved by means of two foreground flash lamps (500 Watt, Elinchrom style 400 FX) each covered with a soft box (Calumet Nova 22) positioned either side of the subject at a 45 degree angle. The distance between the subject and the camera was fixed at five feet.

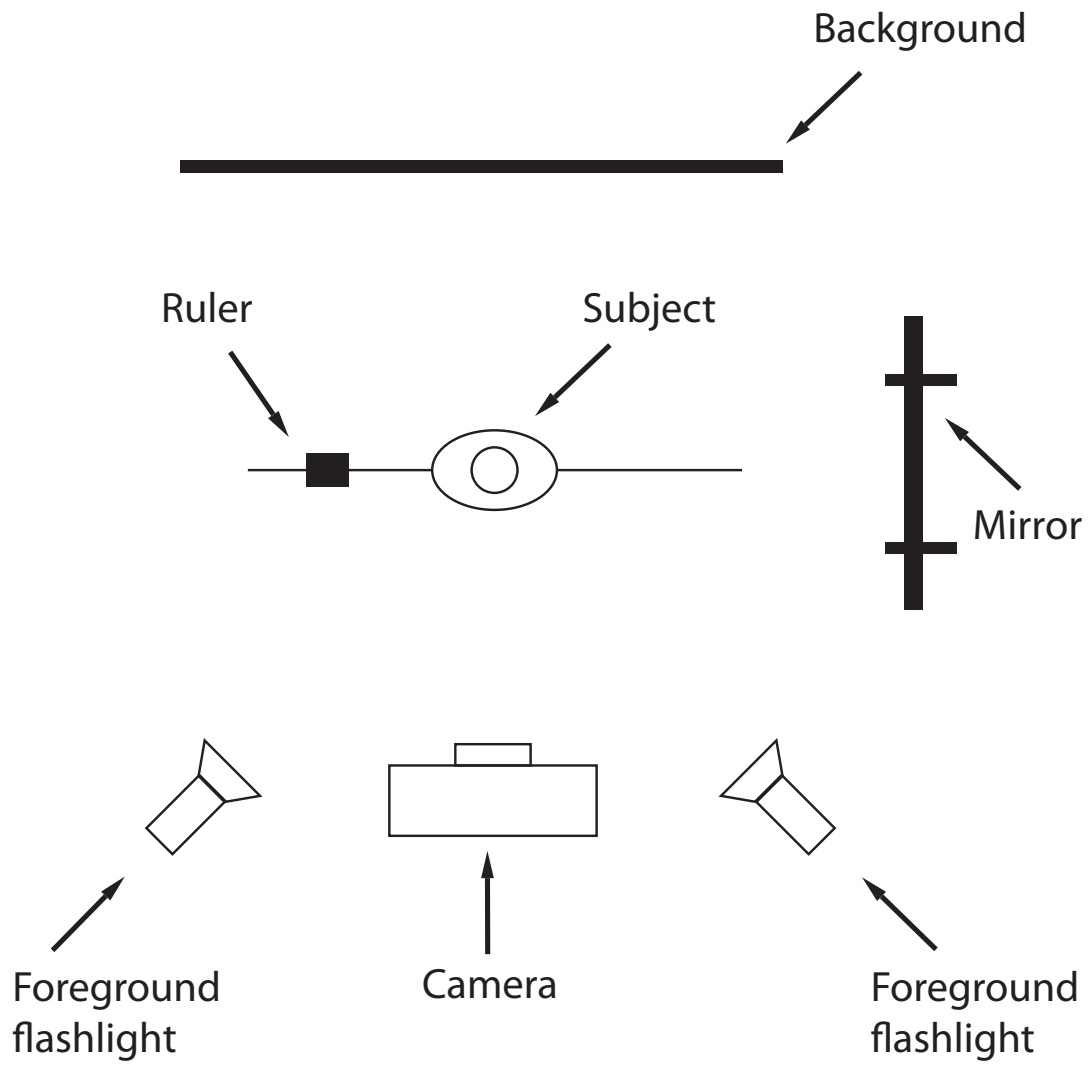


Figure 3.1 Schematic diagram of the photographic set up.

The tripod was adjustable in a vertical direction to allow adjustments to the height of the camera, according to each subject's body height. This ensured the correct horizontal position of the optical axis of the lens of the camera. The camera was used in the manual setting enabling the adjustment of the focal length/focus. The shutter speed was set to 1/125, with the opening of the aperture set to f/22. Digital photographic images were recorded on to a flash drive compact flash card (Microdrive™ 512 MB, IBM, Thailand).

3.3.2 Calibration

A 10 cm metal ruler with a weight attached was suspended from the arm of a tripod to indicate the True Vertical reference line (TV) and positioned behind the subject's chair in the mid-sagittal plane. The ruler scale enabled calibration of photographs so that objective linear measurements could be directly compared. A mirror was positioned approximately 110cm in front of the subject's chair to allow the consistent registration of the natural head position (NHP).

3.3.3 Image capture

Prior to image capture, subjects were asked to remove spectacles, jewellery and makeup and ensure all hair was drawn completely off the face and neck. The subject was then seated on a chair in front of the camera. The subject was positioned so that the profile of the right hand side of the face and the 10cm ruler were both visible in each image. The subject's position was checked to ensure the photograph was taken perpendicular to their midsagittal plane. Images were taken with the subject in natural head position to ensure standardised photographs (Figure 3.2).

As part of the photographic capture, subjects were instructed to:

- keep eyes open,
- adopt the natural head position, by gently moving their head up and down whilst looking in to their eyes in the mirror directly in front of them,
- warned of a flash of light,
- keep perfectly still while the photograph was being taken.
- say “Mississippi”, then swallow and say “N” (guidelines for extra oral photography to obtain rest position natural expression as proposed by Zachrisson, 1998).

Following these instructions, and ensuring the subject had adopted natural head position and the lips were in the rest position, a photograph of each subject’s right profile view was taken.

3.4 Lay Panel Members

The lay panel consisted of a random selection of four males and four females between the ages of 18 and 35 years. The members of the lay panel were all of Caucasian origin from the West of Scotland. Subjective bias was minimised as none of the lay panel had a medical or dental background or prior experience of orthodontic care. Three dimensional images were shown to the lay panel which did not include imagery of the teeth and thus an assessment of facial attractiveness was carried out which excluded dental aesthetics.

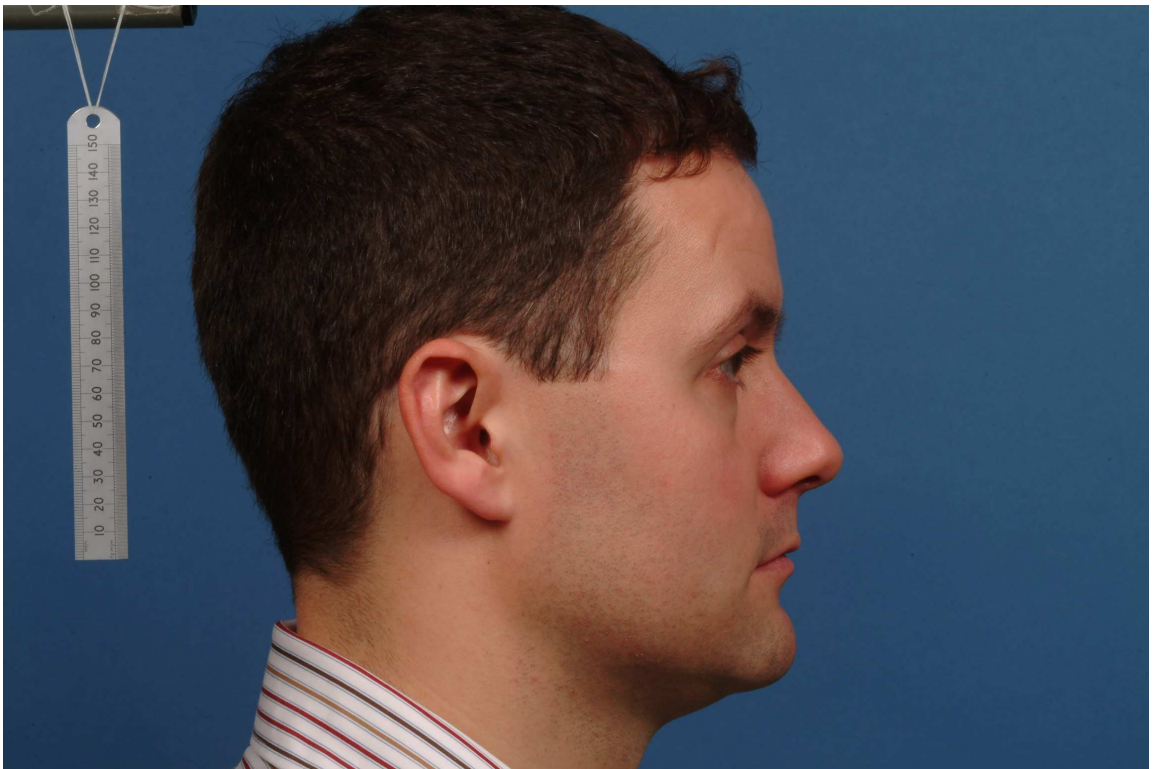


Figure 3.2 Photograph showing right lateral profile view, taken with subject in natural head position with calibration ruler positioned behind the subject in the midsagittal plane

3.5 Rating of Images

The concurrent study of the same sample of 112 volunteers captured by 3D stereophotogrammetry was used for this part of the study. The 3D images of each volunteer were viewed in a frontal view and then rotated to the left and right using GL view software (<http://home.snafu.de/hg/>). During the viewing the screen was captured as a video clip using screen recording software, Auto Screen Recorder (Wisdom Software Inc, Victoria, Canada). Each video clip of 30 seconds duration was embedded into a PowerPoint presentation (Microsoft® Powerpoint 2000, Microsoft Corporation, USA) and saved onto a DVD (Imation, Schipol, The Netherlands). The DVD therefore consisted of consecutive individual video images for the 112 volunteers. The lay panel subsequently rated the images on the DVD at one sitting.

The members of the lay panel members were given instructions on how to rate the images prior to viewing the presentation. They were asked to ignore facial complexion, hair, position of ears and to assess facial attractiveness with respect to facial balance and harmony. The lay panel members rated each image using a 100mm horizontal VAS which was marked with anchors “very unattractive” and “very attractive”. Members of the lay panel indicated the level of attractiveness by drawing a vertical line on the VAS. Each member of the lay panel rated all 112 images in one sitting with alternate male and female images presented.

3.6 Ranking of Images

The VAS scores were ranked from most attractive to least attractive for each subject as judged by the lay panel members. The scores were divided into 3 categories; “most attractive”,

“attractive”, and “least attractive”. Individuals who were assessed as being “most attractive” and “attractive” by at least six members of the lay panel were selected to form the control group. The control group consisted of 16 males and 24 females.

3 Materials and Methods Part II

3.7 Study Design

The study was designed to compare 2D lateral profile photographic views of a group of post-surgical orthognathic patients to a control group of attractive patients. The study was based on the objective measurement of digitised images using angular and linear measurements. The control group of attractive individuals was selected by a lay panel as detailed in Materials and Methods Part I.

Ethical approval was obtained from the Local Area Dental Ethics Committee of North Glasgow University Hospitals NHS Trust, Appendix I.

3.8 Subjects

The post-surgical orthognathic group were recruited from the Dentofacial Deformity clinics at the Glasgow Dental Hospital and the Southern General Hospital Glasgow. Subjects were recruited over a seventeen month period from April 2008 to August 2009. All subjects in the post-surgical orthognathic group had been under the care of one Consultant Oral and Maxillofacial surgeon in the Southern General Hospital, Glasgow. Informed consent was obtained from each subject prior to participation in the study.

3.8.1 Inclusion criteria

- Caucasian individuals from the West of Scotland.
- Both parents originating from the West of Scotland.
- Patients to be aged between 18-35 years of age.
- Post-orthognathic surgical correction of a dentofacial deformity.

3.8.2 Exclusion criteria

- Craniofacial defect or syndrome
- Facial hair
- Non-Caucasian origin
- Not originating from the West of Scotland
- Parents of subjects not originating from the West of Scotland

3.8.3 Sample size calculation

Sample size estimation is determined by four main factors

1. The level of the desired power.
2. The intended statistical test to be used.
3. The smallest clinical significant difference that needs to be detected.
4. The variability of the observed data.

The clinical significance was derived from the results of a previous study and was set at 3 mm (Jones *et al.*, 2007). A search of the literature indicated that the majority of soft tissue facial landmarks of potential interest had a standard deviation of ± 3.0 mm (Arnett *et al.*, 1999). Applying a significance level of 0.05 and a power of 80% a sample size of 16 subjects would

be required (Gardner *et al.*, 1986). This means that within each group a minimum of 16 patients are required.

3.9 Materials

As previously described the post-surgical orthognathic group patients were imaged using the standardised capture protocol (section 3.3.3). This procedure was carried out for the control male and female images and the male and female post-orthognathic surgery images. The soft tissue landmarks used in this study are shown in Figures 3.3 and 3.4, and the landmarks and measurements recorded are detailed in Tables 3.1 to 3.5. Stomion was the landmark used when the subject's lips were competent and all vertical measurements were recorded from this landmark. Stomion superior and stomion inferior were the landmarks identified when the subject's lips were incompetent and all vertical measurements were recorded from these landmarks.

3.9.1 Error study

The validity and reproducibility of the method was assessed by an error study. Six images were randomly selected from each of the 4 groups. Each of the 24 images was landmarked two weeks apart and the data used in the error study.

Table 3.1 Soft tissue landmarks used in the study.

Landmark	Definition
Glabella (G)	The most anterior point of the middle line of the forehead that borders the upper line of the eyebrow.
Nasion (N)	The most concave point located at the nasal root.
Pronasale (Prn)	The most anterior point of the nose tip.
Columella (Cm)	The most inferior and anterior point of the nose.
Subnasale (Sn)	The point where the upper lip joins the columella.
Soft tissue A point (A)	The most concave point between Subnasale and the mucocutaneous limit of the upper lip.
Labiale superior (Ls)	The point that indicates the mucocutaneous limit of the upper lip.
Upper lip anterior (ULA)	The most anterior point on the upper lip.
Stomion superior (Sts)	The most inferior point of the upper lip, also referred to as Upper lip inferior (ULI). This landmark was used in subjects with incompetent lips.
Stomion (Sto)	The point where upper lip contacts lower lip. This landmark was used in subjects with competent lips
Lower lip anterior (LLA)	The most anterior point of the lower lip.
Stomion inferior (Sti)	The most superior point of the lower lip also referred to as Lower Lip Superior (LLS). This landmark was used in subjects with incompetent lips.
Labiale inferior (Li)	The point that indicates the mucocutaneous limit of the lower lip.
Soft tissue B point (B)	The deepest point of the inferior sub labial concavity, also referred to as Supramentale (Sm).
Soft tissue pogonion (Pog)	The most anterior point of the convexity of the chin.
Menton (Me)	The most inferior point of the outline of the chin

Table 3.2 Landmarks used to define clinical angular measurements.

Landmark	Measurement
ULA-Sn-Cm	Nasiolabial angle
Cm-Sn-Ls	Nasiolabial angle
ULA-SN-TV	Upper lip angle
G-Sn-Pog	Facial harmony angle (Facial convexity angle)
G-Prn-Pog	Angle of total facial convexity
L-Sm-Pog	Mentolabial angle
Li-B-Pog	Mentolabial angle

Table 3.3 Landmarks used to define clinical linear horizontal measurements.

Landmark	Definition
G-TV	Glabella to True Vertical (TV)
Prn-V	Pronasale to TV
A-TV	Soft tissue A point to TV
Ls-TV	Labiale superior to TV
ULA-TV	Upper lip anterior to TV
LLA-TV	Lower lip anterior to TV
Li-TV	Labiale inferior to TV
B-TV	Soft tissue B point to TV
Pog-TV	Soft tissue pogonion to TV

Table 3.4 Landmarks used to define clinical facial harmony values and the linear horizontal differences between landmarks relative to the True Vertical.

Landmark	Measurement
B-Pog	Soft tissue B point to soft tissue pogonion
LLA-Pog	Lower lip anterior to soft tissue pogonion
ULA-LLA	Upper lip anterior to lower lip anterior
A-B	Soft tissue A point to soft tissue B point
G-A	Glabella to soft tissue A point
G-Pog	Glabella to soft tissue pogonion

Table 3.5 Landmarks used to define clinical linear vertical measurements. Alternative names are in brackets.

Landmark	Definition
G-Sn	Middle facial third height
N-Sn	Vertical nasal length
N-Me	Anterior face height
Sn-Me	Inferior facial third height
Sn-ULI (Sn-Sti)	Length of upper lip (Incompetent lips)
Sn-Sto	Length of upper lip (Competent lips)
ULI-LLS (Sts-Sti)	Interlabial gap
LLS-Me	Length of lower lip (Incompetent lips)
Sto-Me	Length of lower lip (Competent lips)
Sti-B	Length of lower lip (Incompetent lips)
Sto-B	Length of lower lip (Competent lips)
Ls-Sts	Vermillion of upper lip (Incompetent lips)
Ls-Sto	Vermillion of upper lip (Competent lips)
Li-Sti	Vermillion of lower lip (Incompetent lips)
Li-Sto	Vermillion of lower lip (Competent lips)
B-Me	Chin height

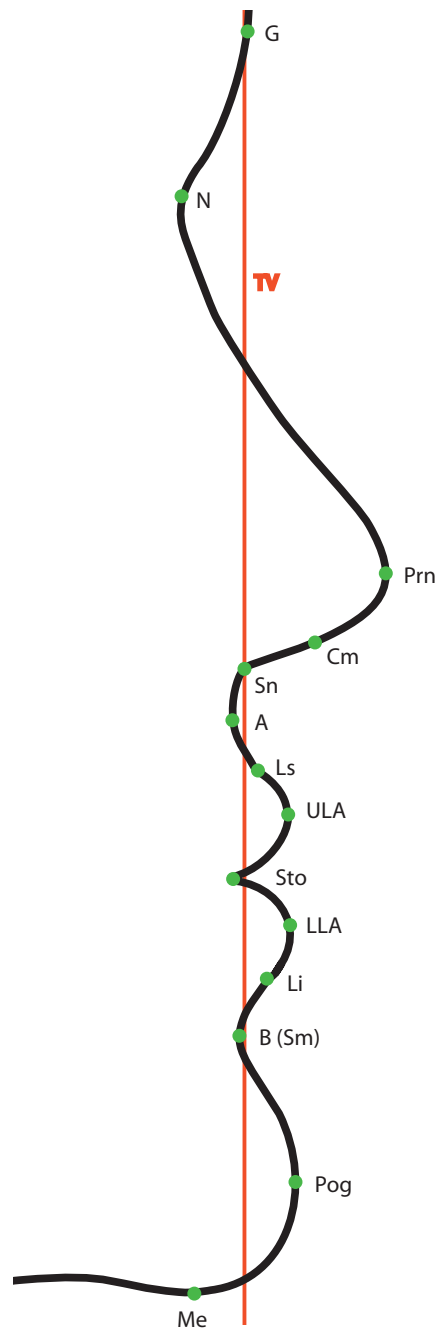


Figure 3.3 Right profile image with competent lips showing the soft tissue landmarks with the True Vertical (TV) reference line used in this study. Alternative names for landmarks are in brackets.

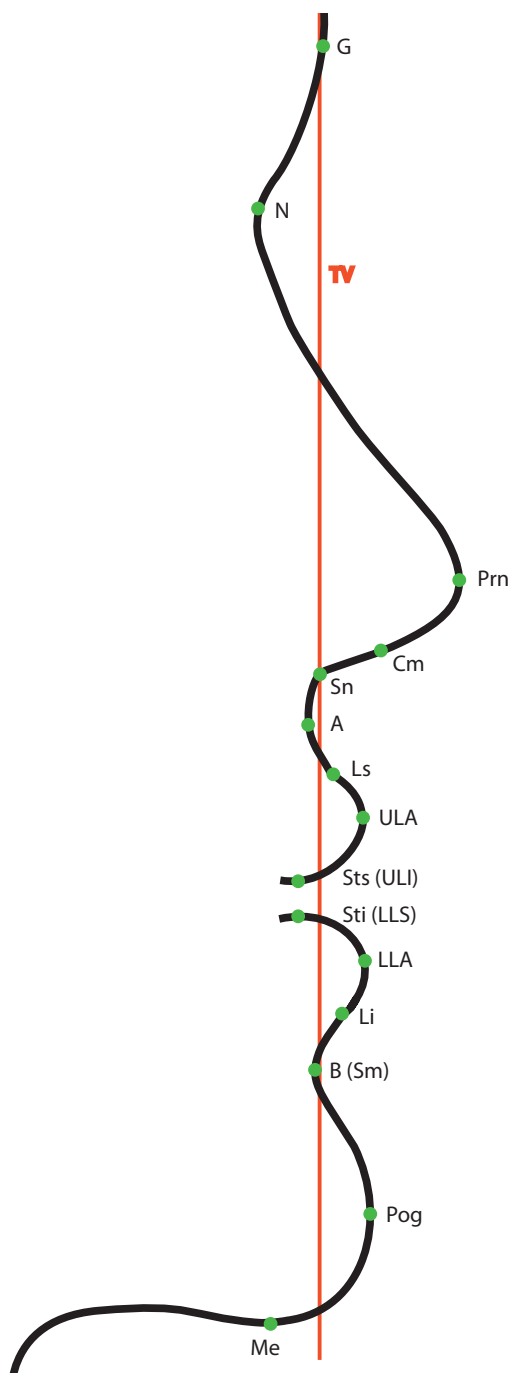


Figure 3.4 Right profile image with incompetent lips showing the soft tissue landmarks with the True Vertical (TV) reference line used in this study. Alternative names for landmarks are in brackets.

3.10 Analysis of Digital Images

The digital images of the attractive control group and the post-surgery orthognathic group were analysed using Adobe Photoshop (Version 7.0). The images were imported and a separate layer which recorded each stage of the analysis was created, and for each stage of analysis, a new layer was created. Each layer showed the individual measurements which could be manipulated independently of one another and allowed the operator view all or some of the layers at any one time. All of the data was analysed by one operator. There were 4 key stages to the data analysis:

- Construction of a true vertical plane passing through subnasale.
- Magnification calculation
- Landmark identification.
- Measurements – angular and linear.

3.10.1 Construction of a true vertical line passing through subnasale

A true vertical reference line was constructed parallel to the ruler visible in the photograph. The constructed line passed through subnasale.

3.10.2 Magnification calculation

The magnification factor was determined by using Adobe Photoshop software with reference to the scale of the 10cm True Vertical (TV) ruler recorded in each image. This was calculated by measuring 5cm on the ruler and recording the equivalent number of pixels this represented using the software measuring tool. The magnification factor allowed correction of the subsequent linear measurements.

3.10.3 Landmark identification

The landmarks were identified using Adobe Photoshop and recorded using 0.2mm diameter coloured circles. All linear measurements were calculated in millimetres (mm) and angular measurements in degrees ($^{\circ}$).

3.11 Measurements

3.11.1 Facial angles

The angular measurements recorded are shown in Figures 3.5 and 3.6. Adobe Photoshop was used to construct and calculate the angles by joining specific soft tissue landmarks. The angular measurement was calculated using the Adobe Photoshop measurement tool.

3.11.2 Linear horizontal distances

The linear horizontal measurements recorded are shown in Figure 3.7. Adobe Photoshop was used to construct and calculate the distances by joining the specific soft tissue landmarks, e.g. nasal projection was constructed by drawing a line perpendicular from Pronasale to a True Vertical line through Subnasale. Measurements were calculated using the Adobe Photoshop measurement tool. To denote the relative position of the measurements to the True Vertical, horizontal distances anterior to TV were assigned a positive value, and posterior distances to this line were assigned a negative value.

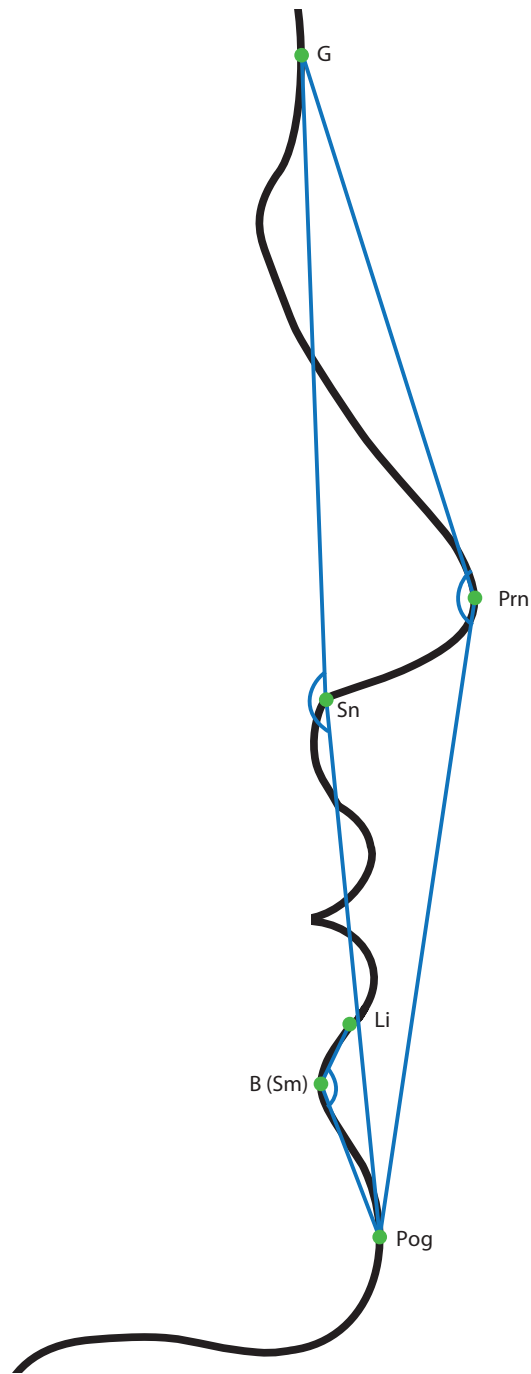


Figure 3.5 Angular measurements of the study; G-Sn-Pog, G-Prn-Pog and Li-Sn-Pog

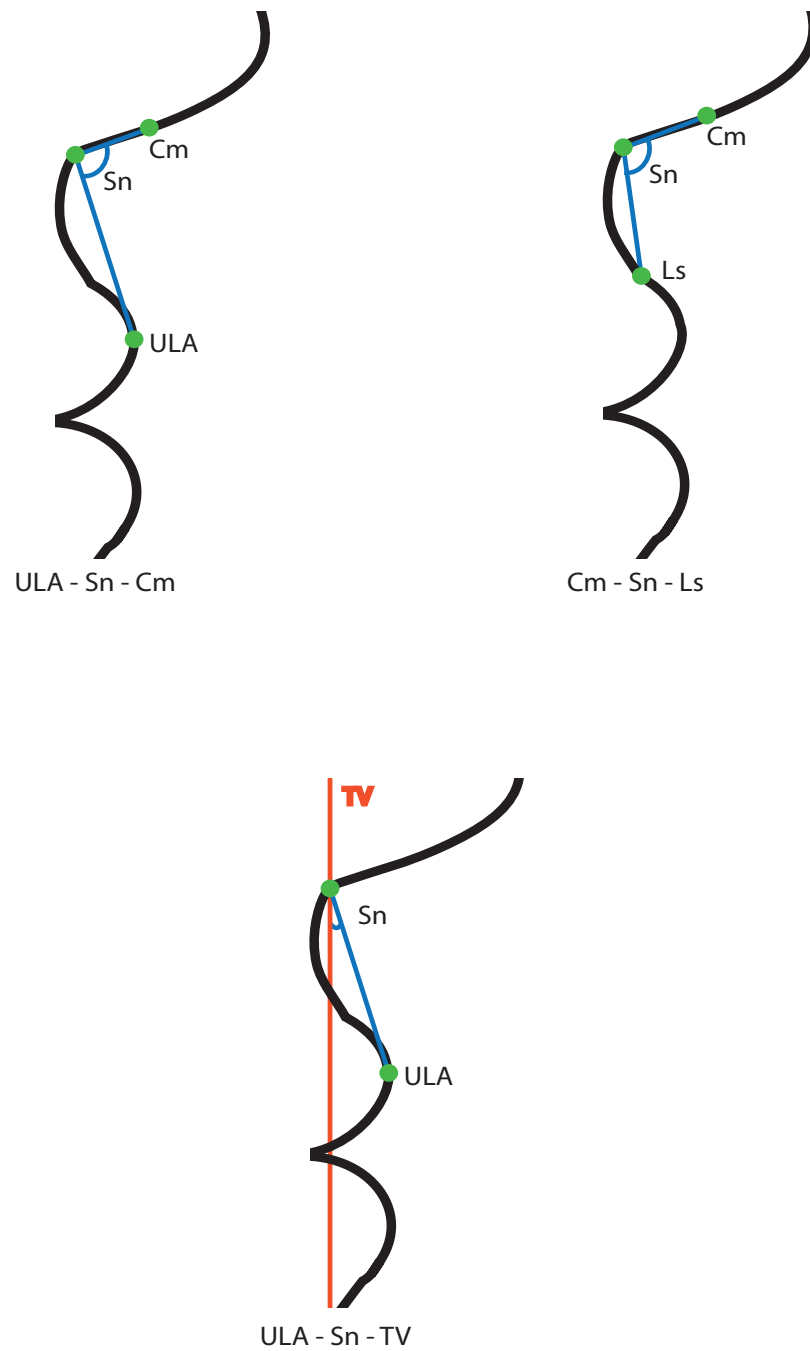


Figure 3.6 Angular measurements of the study; nasiolabial angle (ULA-Sn-Cm), nasiolabial angle (Cm-Sn-Ls), upper lip angle (ULA-Sn-TV)

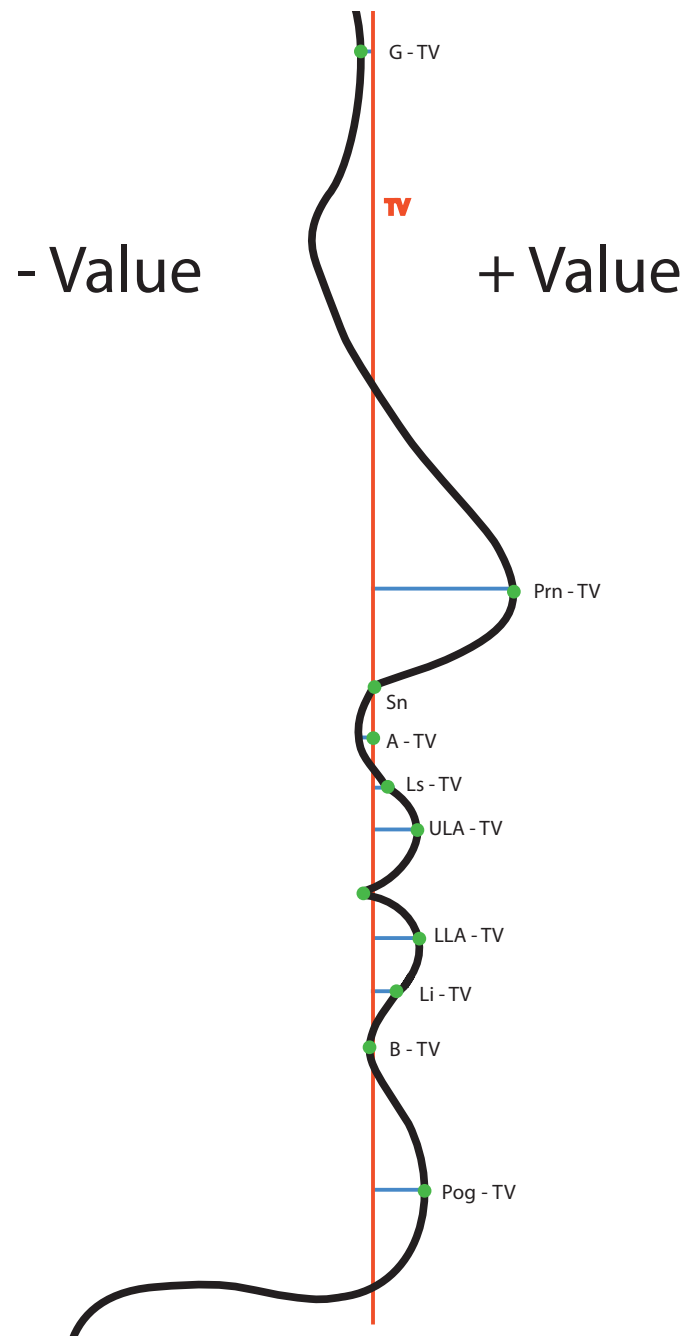


Figure 3.7 Linear horizontal measurements relative to the True Vertical (TV) reference line through subnasale as used in this study. To indicate relative position to the TV measurements to the right side of TV are notated with a positive (+) value and measurements to the left of TV are notated with a negative (-) value.

3.11.3 Facial harmony value

The clinical facial harmony measurements that determine facial balance are shown in Figure 3.8. Adobe Photoshop was used to construct and calculate the linear horizontal differences between the landmarks, relative to the True Vertical through Subnasale.

3.11.4 Linear vertical distances

The linear vertical measurements recorded are shown in Figures 3.9 and 3.10. Adobe Photoshop was used to construct and calculate the distances by joining specific soft tissue landmarks e.g., anterior face height (Nasion-Menton) horizontal lines perpendicular to a True Vertical through Subnasale were constructed from the soft tissue landmarks (Nasion and Menton) and the measurement tool within Adobe Photoshop was used to construct a perpendicular vertical line between the two horizontal lines and measure its length. Stomion was the landmark used when the subject's lips were competent and all vertical measurements were recorded from this landmark. Stomion superior and stomion inferior were the landmarks identified when the subject's lips were incompetent and all vertical measurements were recorded from these landmarks.

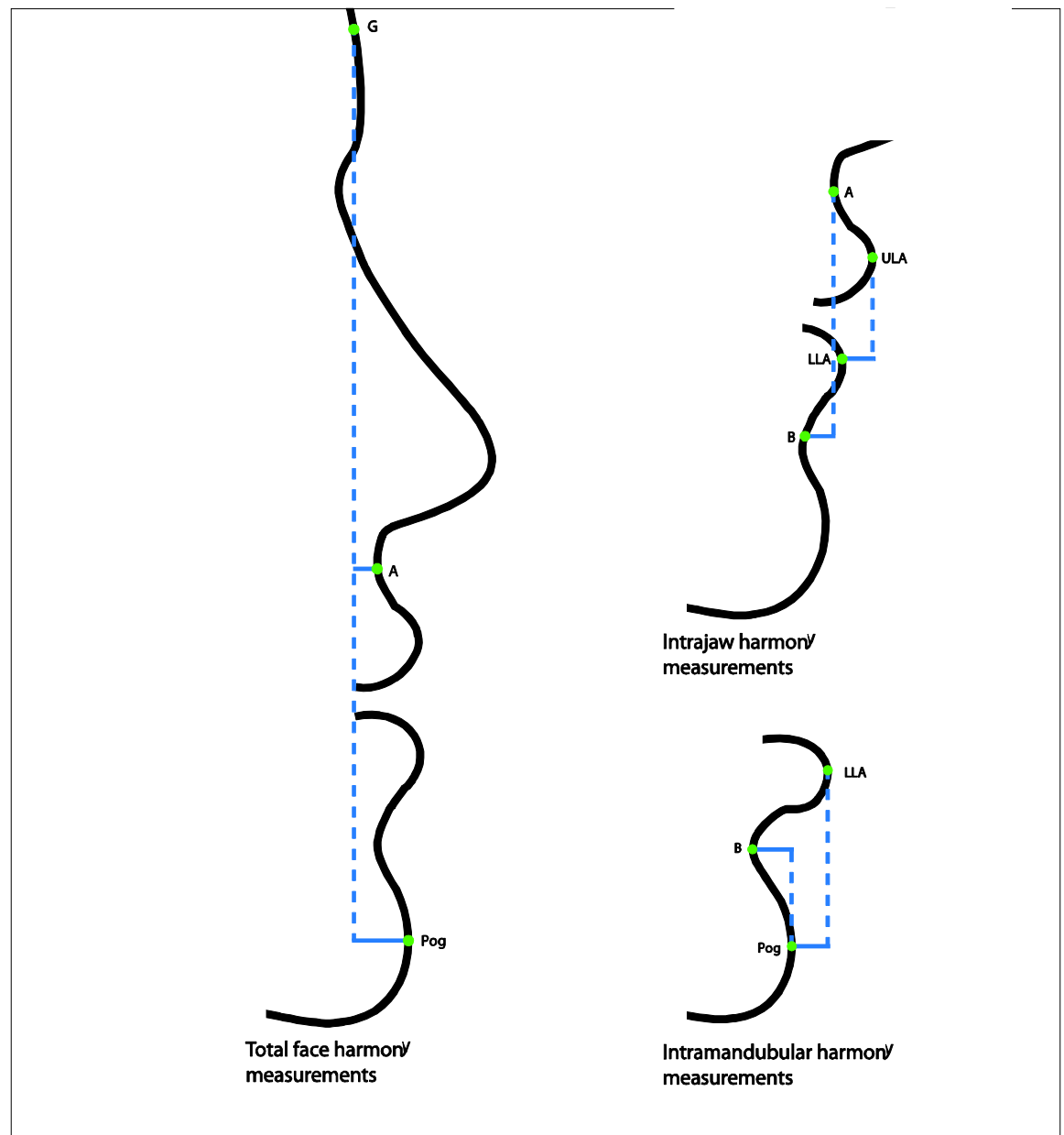


Figure 3.8 Facial harmony measurements used in the study. Facial harmony values are the facial relationships that determine facial balance and harmony between landmarks. All values are calculated as the linear horizontal distance between two landmarks perpendicular to a TV through subnasale. Total face harmony measurements (G-A) and (G-Pog). Intrajaw harmony measurements (A-B) and (ULA-LLA). Intramandibular harmony measurements (LLA-Pog) and (B-Pog).

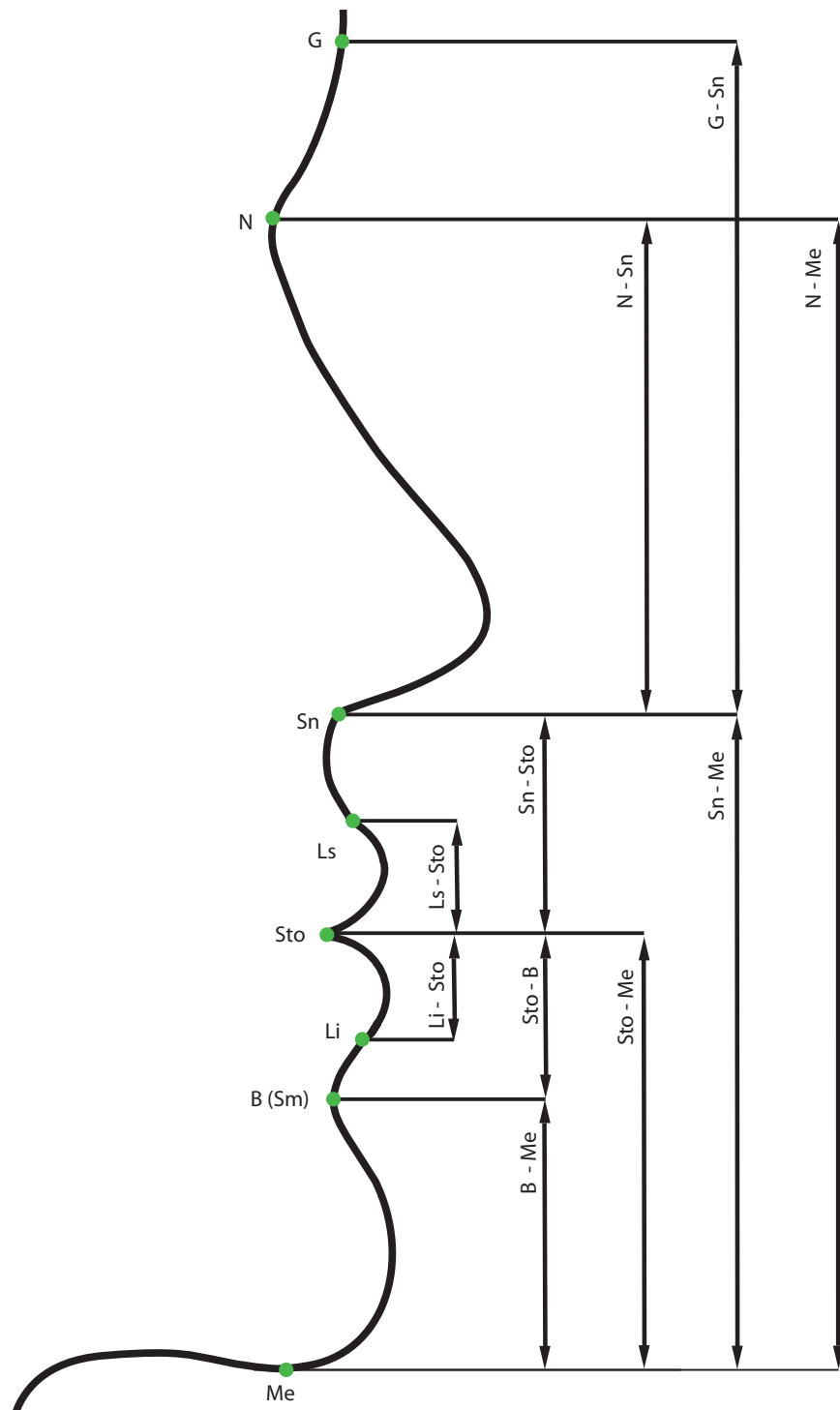


Figure 3.9 Linear vertical measurements used in the study as shown in an image with competent lips

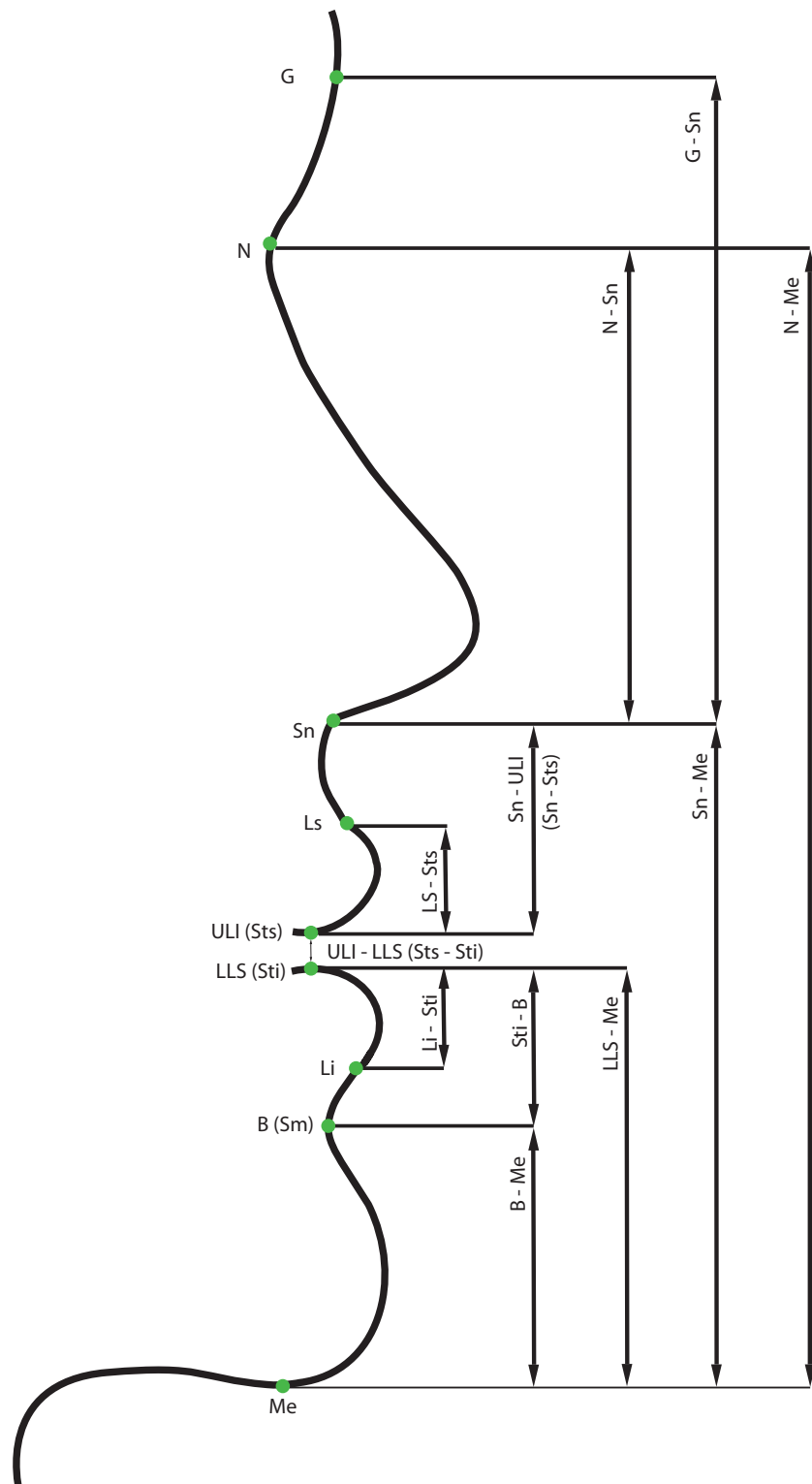


Figure 3.10 Linear vertical measurements used in the study as shown in an image with incompetent lips

3.12 Statistical Analysis

The angular, horizontal and linear measurements were analysed using SPSS version 15.0 and found to be normally distributed. Descriptive statistics provided mean and standard deviations for the measurements for the groups; control male and control female, control male and orthognathic male, control female and orthognathic female. An independent Student's t-test was used to compare the means of the measurements for the groups, calculate the mean difference between the groups, confidence interval and the level of significance. Equal variances were not assumed.

A linear horizontal or vertical measurement was regarded as clinically significant when greater or equal to 3mm (Jones *et al.*, 2007).

Chapter Four

Results

4 Results Part I

4.1 Sample Characteristics

During the period of data collection a total 61 females and 51 males agreed to take part in the study and were viewed by the lay panel. After dividing the data into three categories – most attractive, attractive and least attractive and choosing individuals who were thought of as being most attractive and attractive by at least 6 lay panel members, 16 “control” males and 24 “control” females were selected.

Gender	Number (N)	Mean age (Yrs)	Range (Yrs)
Male	16	25.4	19 - 32
Female	24	21.3	18 - 30

4.2 Error of the Method

The results of the error of the method are presented in Tables 4.1 – 4.2. Systematic error was assessed by paired t-tests and random error assessed by coefficients of reliability (Houston, 1983). No systematic errors were observed. All coefficients of reliability were above 90%.

Table 4.1 Reproducibility of landmark identification, X coordinates.

Landmark	Mean ¹	SD	p-value ²	CR ³
Glabella (G)	-0.04	0.43	0.67	0.99
Nasion (N)	-0.10	0.53	0.36	0.99
Pronasale (Prn)	-0.03	0.55	0.79	0.99
Columella (Cm)	0.47	0.91	0.20	0.99
Subnasale (Sn)	-0.22	1.35	0.44	0.99
Soft tissue A point (A)	0.03	0.44	0.78	0.99
Labiale superior (Ls)	0.01	0.49	0.98	0.99
Upper Lip Anterior (ULA)	0.08	0.84	0.67	0.99
Stomion superior (Sts)	0.02	1.57	0.84	0.99
Stomion (Sto)	0.19	0.81	0.28	0.99
Lower Lip Anterior (LLA)	-0.25	1.20	0.56	0.99
Stomion inferior (Sti)	-0.23	0.56	0.54	0.99
Labiale inferior (Li)	-0.24	0.64	0.10	0.99
Soft tissue B point (B)	0.17	0.70	0.24	0.99
Soft tissue Pogonion (Pog)	0.17	0.47	0.86	0.99
Menton (Me)	0.96	1.21	0.10	0.99

1 Mean difference between repeat landmark identification (mm)

2 Testing for significant differences from zero using paired t-tests

3 CR = Pearson's coefficient of reliability

Table 4.2 Reproducibility of landmark identification, Y coordinates.

Landmark	Mean ¹	SD	p-value ²	CR ³
Glabella (G)	-0.41	0.77	0.12	0.99
Nasion (N)	0.46	1.46	0.13	0.99
Pronasale (Prn)	-0.25	1.17	0.32	0.99
Columella (Cm)	-0.39	0.73	0.02	0.99
Subnasale (Sn)	-0.09	0.96	0.64	0.99
Soft tissue A point (A)	-0.05	1.20	0.85	0.99
Labiale superior (Ls)	-0.28	0.49	0.16	0.99
Upper Lip Anterior (ULA)	-0.12	0.59	0.34	0.99
Stomion superior (Sts)	-0.03	0.42	0.90	0.99
Stomion (Sto)	-0.10	0.42	0.28	0.99
Lower Lip Anterior (LLA)	0.39	0.45	0.52	0.99
Stomion inferior (Sti)	-0.57	0.81	0.35	0.99
Labiale inferior (Li)	0.10	0.52	0.34	0.99
Soft tissue B point (B)	-0.23	0.90	0.23	0.99
Soft tissue Pogonion (Pog)	-0.72	0.89	0.20	0.99
Menton (Me)	-0.49	0.76	0.15	0.99

1 Mean difference between repeat landmark identification (mm)

2 Testing for significant differences from zero using paired t-tests

3 CR = Pearson's coefficient of reliability

4.3 Control Males and Control Females

Table 4.3 presents the angular measurement results for the male and female control groups including the mean, standard deviation and descriptive statistics and tests for significant differences between control males and females. In all cases there were no statistically significant differences between the control males and females for angular measurements. The nasiolabial angle was larger or more obtuse in the female group than the male group. The nasiolabial angle (Cm-Sn-Ls) also showed the largest mean difference (4.1°). The males had larger mean values for the following measurements:

- facial harmony value
- angle of total convexity
- mentolabial angle.

The results for horizontal measures relative to a True Vertical (TV) are shown in Table 4.4. For all the measurements the values were larger in the female group than in the male group, except for glabella to TV and pronasale to TV. There was no clinical or statistical difference between all the linear horizontal measurements for male and female groups. The 95% confidence for the mean difference was greater than 3mm for the following measurements:

- glabella to TV
- B point to TV
- pogonion to TV.

Table 4.3 Angular measurements (degrees) comparing control males and females showing means, standard deviations and tests for significant differences between control males and control females

Measurement	Landmark ¹	Male		Female		Difference between means	P – Value ²	95% CI for Mean Difference ³	
		Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
Nasiolabial angle	ULA - Sn - Cm	108.5	11.6	112.1	8.9	-3.6	0.299	-10.7	3.4
	Cm - Sn - Ls	108.8	12.1	112.9	9.8	-4.1	0.264	-11.6	3.3
Upper Lip Angle	ULA - Sn - TV	5.6	4.1	6.3	4.7	-0.7	0.628	-3.5	2.2
Facial Harmony Angle (Facial Convexity Angle)	G - Sn - Pog	169.9	4.6	167.7	4.6	2.2	0.148	-0.8	5.2
Angle of Total Facial Convexity	G - Prn - Pog	141.2	4.5	139.4	4.2	1.8	0.213	-1.1	4.7
Mentolabial Angle	Li - Sm - Pog	133.3	11.5	131.9	10.1	1.4	0.690	-5.8	8.7

1. Full names of landmarks and abbreviations are listed in the appendix.

2. p-values calculated using Student's t-test.

3. 95% confidence intervals for the mean difference.

Table 4.4 Linear horizontal measurements (mm) relative to True Vertical (TV) comparing control males and females showing means, standard deviations and tests for significant differences between control males and females.

Measurement (Projection to True Vertical, TV)	Landmark ¹	Male		Female		Difference between means	P – Value ²	95% CI for Mean Difference ³	
		Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
Glabella to TV	G - TV	-4.1	6.0	-2.5	5.3	-1.7	0.374	-5.5	2.1
Pronasale to TV	Prn - TV	16.7	2.4	16.3	1.7	0.4	0.542	-1.0	1.9
A point to TV	A - TV	-2.3	1.1	-2.5	1.3	0.2	0.517	-0.5	1.0
Labiale superior to TV	Ls - TV	-0.6	1.8	-1.0	1.8	0.5	0.430	-0.7	1.6
Upper lip anterior to TV	ULA - TV	-0.7	1.7	-0.7	2.0	0	0.966	-1.2	1.2
Lower lip anterior to TV	LLA - TV	-3.4	2.4	-3.6	2.5	0.2	0.824	-1.4	1.8
Labiale inferior to TV	Li - TV	-4.1	2.8	-5.0	2.5	0.9	0.322	-0.9	2.7
B point to TV	B - TV	-9.9	3.9	-10.0	4.9	0.1	0.932	-2.7	3.0
Pogonion to TV	Pog - TV	-6.0	5.1	-8.0	3.9	2.1	0.187	-1.1	5.2

1. Full names of landmarks and abbreviations are listed in the appendix.

2. p-values calculated using Student's t-test.

3. 95% confidence intervals for the mean difference.

Figures in red indicate statistical significance.

Figures in bold indicate clinical significance.

The results for facial harmony values are shown in Table 4.5. In the majority of measurements the values were larger in the female group than the male group, except for:

- B point to pogonion
- glabella to A point.

There was no statistical difference between the facial harmony values for males and females except for B point to pogonion ($p = 0.045$), but this was not clinically significant. It is interesting to note that glabella to pogonion was clinically significant (3.3mm) but not statistically significant ($p = 0.254$). This measurement showed the largest clinical significance compared to all the other facial harmony values between the groups. The 95% confidence for the mean difference was greater than 3mm for the following measurements:

- glabella to A point
- glabella to pogonion.

The results for linear vertical measures are shown in Table 4.6. For all measurements the values were larger in the male group compared to the female group except for:

- vermillion of upper lip
- vermillion of lower lip.

Anterior face height in the male group had the largest mean difference (12.2mm) followed by inferior facial third (9.3mm), length of lower lip (LLS-Me) (6.8mm) and chin height (6.6mm). The following measurements were clinically and statistically significant:

- vertical nasal length
- anterior face height
- inferior facial third
- length of lower lip (LLS-Me)

- chin height.

All of these measurements were highly statistically significant ($p < 0.001$) with the exception of the length of upper lip measurement ($p = 0.003$). In addition to the previously mentioned clinically significant measurements, the 95% confidence for the mean difference was greater than 3mm for:

- middle facial third
- length of lower lip (LLS-B).

Table 4.5 Facial harmony values (mm), the linear horizontal difference between landmarks as calculated from the True Vertical (TV) comparing control males and females showing means, standard deviations and tests for significant differences between control males and females.

Measurement (Projection to True Vertical, TV)	Landmark ¹	Male		Female		Difference between means	P – Value ²	95% CI for Mean Difference ³	
		Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
B point to Pogonion	B - Pog	3.9	2.0	2.6	1.7	1.3	0.045	0	2.5
Lower lip anterior to Pogonion	LLA - Pog	4.1	3.1	4.8	2.6	-0.8	0.434	-2.7	1.2
Upper lip anterior to Lower lip anterior	ULA - LLA	2.9	1.9	2.9	1.6	0	0.947	-1.1	1.2
A point to B point	A - B	7.6	3.8	8.2	2.6	-0.5	0.63	-2.8	1.7
Glabella to A point	G - A	2.4	5.7	0.7	4.9	1.7	0.341	-1.9	5.2
Glabella to Pogonion	G - Pog	-1.2	9.5	-4.5	7.4	3.3	0.254	-2.5	9.1

1. Full names of landmarks and abbreviations are listed in the appendix.
2. p-values calculated using Student's t-test.
3. 95% confidence intervals for the mean difference.
Figures in red indicate statistical significance.
Figures in bold indicate clinical significance.

Table 4.6 Linear vertical measurements (mm) comparing control males and females showing means, standard deviations and tests for significant differences between control males and females.

Measurement	Landmark ¹	Male		Female		Difference between means	P – Value ²	95% CI for Mean Difference ³	
		Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
Middle facial third	G - Sn	69.3	3.4	68.1	4.2	1.2	0.316	-1.2	3.7
Vertical nasal length	N - Sn	53.2	2.5	50.3	2.7	2.8	0.002	1.1	4.5
Anterior face height	N - Me	127.9	7.8	115.7	6.3	12.2	< 0.001	7.4	17.0
Inferior facial third	Sn - Me	73.8	5.5	64.5	3.5	9.3	< 0.001	6.1	12.6
Length of upper lip	Sn – ULI (Sn – Sts) Sn - Sto	22.2	1.8	20.4	1.5	1.8	0.003	0.7	2.9
Interlabial gap	ULI – LLS (Sts – Sti)	1.3	2.4	0.8	2.0	0.5	0.494	-1.0	2.0
Length of lower lip	LLS – Me (Sti – Me) Sto – Me	50.1	4.1	43.3	2.5	6.8	< 0.001	4.4	9.2
	Sti – B (LLS – B)	18.1	3.1	17.0	2.1	1.1	0.221	-0.7	3.0
Vermillion of upper lip	Ls - Sts	6.8	1.5	7.3	1.1	-0.5	0.312	-1.4	0.5
Vermillion of lower lip	Li - Sti	8.5	1.9	9.3	0.8	-0.8	0.126	-1.8	0.2
Chin height	B - Me	32.6	3.9	26.0	3.2	6.6	< 0.001	4.2	9.0

1. Full names of landmarks and abbreviations are listed in the appendix.

2. p-values calculated using Student's t-test.

3. 95% confidence intervals for the mean difference.

4. Figures in red indicate statistical significance.
Figures in bold indicate clinical significance.

4 Results Part II

4.4 Sample Characteristics

During the period of data collection a total 17 females and 16 males agreed to take part in the study.

Gender	Number (n)	Mean age (Yrs)	Range (Yrs)
Male	16	22.4	16 - 34
Female	17	23.8	17 - 35

4.5 Control Males and Orthognathic Males

Table 4.7 shows the angular measurements for the male control and orthognathic groups including means, standard deviations and descriptive statistics and tests for significant differences between control males and orthognathic males. There were no statistically significant differences between the control males and orthognathic males for angular measurements. The mentolabial angle in the orthognathic group showed the largest mean difference (6.2°). Orthognathic males had larger mean values for the angle of total facial convexity and upper lip angle. The orthognathic male group had smaller mean values for the remaining angles; nasiolabial and facial harmony angles. Clinical significance cannot be commented on as there is no absolute figure to indicate clinical significance.

Table 4.7 Angular measurements (degrees) for control males and orthognathic males including means, standard deviations and tests for significant differences between control males and orthognathic males.

Measurement	Landmark ¹	Control		Orthognathic		Difference between means	P – Value ²	95% CI for Mean Difference ³	
		Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
Nasiolabial angle	ULA - Sn - Cm	108.4	11.6	107.6	9.9	-0.9	0.819	-8.7	6.9
	Cm - Sn - Ls	108.8	12.1	107.4	10.3	-1.4	0.730	-9.5	6.8
Upper Lip Angle	ULA - Sn - TV	5.6	4.1	7.7	5.2	2.1	0.214	-1.3	5.5
Facial Harmony Angle (Facial Convexity Angle)	G - Sn - Pog	169.9	4.6	169.1	5.5	-0.8	0.676	-4.4	2.9
Angle of Total Facial Convexity	G - Prn - Pog	141.1	4.5	141.2	4.9	0	0.994	-3.4	3.4
Mentolabial Angle	Li - Sm - Pog	133.3	11.5	139.5	13.9	6.2	0.179	-3.0	15.4

4. Full names of landmarks and abbreviations are listed in the appendix.

5. p-values calculated using Student’s t-test.

6. 95% confidence intervals for the mean difference.

Figures in red indicate statistical significance.

Figures in bold indicate clinical significance.

The results for linear horizontal measures relative to a True Vertical (TV) are shown in Table 4.8. In the majority of measurements the values were larger in the control group except for glabella to TV. There was no statistical difference between the linear horizontal measurements for the two groups. B point to TV showed the largest clinical significance compared to all other linear horizontal measures between the control and orthognathic male group, and was the only clinically significant (3.3mm) difference. The 95% confidence for the mean difference was greater than 3mm for the following measurements:

- glabella to TV
- upper lip anterior to TV
- labiale inferior to TV
- B point to TV
- pogonion to TV

The results for facial harmony values are shown in Table 4.9. All of the facial harmony measurements were not clinically or statistically significant except for Glabella to A point and Glabella to pogonion which were clinically significant (2.9mm) and (4.3mm) respectively, but these were not statistically significant. Glabella to pogonion in the orthognathic group showed the largest mean difference (4.3 mm). B point to pogonion, upper lip anterior to lower lip anterior and A point to B point measurements were larger in the control group. The 95% confidence for the mean difference was greater than 3mm for the following measurements:

- A point to B point
- glabella to A point
- glabella to pogonion

Table 4.8 Linear horizontal measurements (mm) relative to True Vertical (TV) comparing control males and orthognathic males showing means, standard deviations and tests for significant differences between control males and orthognathic males.

Measurement (Projection to True Vertical, TV)	Landmark ¹	Control		Orthognathic		Difference between means	P – Value ²	95% CI for Mean Difference ³	
		Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
Glabella to TV	G - TV	-4.1	6.0	-6.2	5.2	-2.1	0.308	-6.1	2.0
Pronasale to TV	Prn - TV	16.7	2.4	16.2	2.1	-0.6	0.488	-2.2	1.1
A point to TV	A - TV	-2.3	1.1	-1.8	1.4	0.4	0.364	-0.5	1.3
Labiale superior to TV	Ls - TV	-0.6	1.8	0.5	2.6	1.1	0.198	-0.6	2.7
Upper lip anterior to TV	ULA - TV	-0.7	1.7	0.7	2.8	1.4	0.105	-0.3	3.1
Lower lip anterior to TV	LLA - TV	-3.4	2.4	-1.0	4.1	2.4	0.051	0	4.9
Labiale inferior to TV	Li - TV	-4.1	2.8	-1.8	4.0	2.3	0.072	-0.2	4.8
B point to TV	B - TV	-9.9	3.9	-6.6	5.8	3.3	0.074	-0.3	6.8
Pogonion to TV	Pog - TV	-6.0	5.1	-4.3	5.9	1.7	0.393	-2.3	5.7

1. Full names of landmarks and abbreviations are listed in the appendix.
 2. p-values calculated using Student's t-test.
 3. 95% confidence intervals for the mean difference.
 Figures in red indicate statistical significance.
 Figures in bold indicate clinical significance.

Table 4.9 Facial harmony values (mm), the linear horizontal difference between landmarks as calculated from the True Vertical (TV) comparing control males and orthognathic males showing means, standard deviations and tests for significant differences between control males and orthognathic males.

Measurement (Projection to True Vertical, TV)	Landmark ¹	Control		Orthognathic		Difference between means	P – Value ²	95% CI for Mean Difference ³	
		Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
B point to Pogonion	B - Pog	3.9	2.0	3.0	1.9	-0.9	0.216	-2.3	0.5
Lower lip anterior to Pogonion	LLA - Pog	4.1	3.1	4.2	2.9	0.2	0.861	-2.0	2.4
Upper lip anterior to Lower lip anterior	ULA - LLA	2.9	1.9	2.3	1.6	-0.6	0.359	-1.9	0.7
A point to B point	A - B	7.6	3.8	5.9	4.1	-1.7	0.229	-4.6	1.2
Glabella to A point	G - A	2.4	5.7	5.3	4.0	2.9	0.104	-0.6	6.5
Glabella to Pogonion	G - Pog	-1.2	9.9	3.0	6.6	4.3	0.151	-1.7	10.2

1. Full names of landmarks and abbreviations are listed in the appendix.
 2. p-values calculated using Student's t-test.
 3. 95% confidence intervals for the mean difference.
 Figures in red indicate statistical significance.
 Figures in bold indicate clinical significance.

Table 4.10 shows the results for linear vertical measures. In all the measurements the values in the orthognathic male group were larger than the control group except for vertical nasal length, anterior face height, interlabial gap and chin height. There was no statistical difference between the vertical measurements except for the vermillion of the upper lip ($p = 0.003$), but this was not clinically significant (1.8mm). Length of the lower lip (Sti – B) was the only clinically significant measurement (2.2mm) but was not statistically significant ($p = 0.104$). The 95% confidence for the mean difference was greater than 3mm for all measurements except:

- interlabial gap
- vermillion of lower lip

4.6 Control Females and Orthognathic Females

Table 4.11 shows the angular measurements for the female control and female orthognathic groups including means, standard deviations and descriptive statistics and tests for significant differences between control females and orthognathic females. There was no statistical difference between the angular measurements for the female control and female orthognathic groups, except for the nasiolabial angles (ULA-Sn-Cm) ($p = 0.020$) and (Cm-Sn-Ls) ($p = 0.006$). Nasiolabial angle (Cm-Sn-Ls) in female controls showed the largest mean difference (-8.1°). The female orthognathic group compared to the female control group had smaller:

- nasiolabial angles
- upper lip angles
- mentolabial angles

The orthognathic female group had larger mean values for the remaining angles:

- facial harmony angle
- angle of total facial convexity.

Table 4.10 Linear vertical measurements (mm) comparing control males and orthognathic males showing means, standard deviations and tests for significant differences between control males and orthognathic males.

Measurement	Landmark ¹	Control		Orthognathic		Difference between means	P – Value ²	95% CI for Mean Difference ³	
		Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
Middle facial third	G - Sn	69.3	3.4	69.3	6.0	0.1	0.977	-3.5	3.6
Vertical nasal length	N - Sn	53.2	2.5	52.7	5.2	-0.5	0.736	-3.5	2.5
Anterior face height	N - Me	127.9	7.8	127.4	7.5	-0.4	0.889	-5.9	5.2
Inferior facial third	Sn - Me	73.8	5.5	74.9	6.3	1.0	0.628	-3.3	5.3
Length of upper lip	Sn – ULI (Sn – Sts) Sn - Sto	22.2	1.8	23.7	2.9	1.5	0.059	-0.1	3.0
Interlabial gap	ULI – LLS (Sts – Sti)	1.3	2.4	1.1	2.1	-0.2	0.781	-1.9	1.4
Length of lower lip	LLS - Me	50.1	4.1	50.4	4.2	0.3	0.823	-2.7	3.3
	Sti - B	18.1	3.1	20.3	4.3	2.2	0.104	-0.5	4.9
Vermillion of upper lip	Ls - Sts	6.8	1.5	8.6	1.7	1.8	0.003	0.7	3.0
Vermillion of lower lip	Li - Sti	8.5	1.9	9.1	2.7	0.6	0.458	-1.1	2.3
Chin height	B - Me	32.6	3.9	30.7	3.7	-1.9	0.172	-4.6	0.9

1. Full names of landmarks and abbreviations are listed in the appendix.

2. p-values calculated using Student's t-test.

3. 95% confidence intervals for the mean difference.

Figures in red indicate statistical significance.

Figures in bold indicate clinical significance.

Table 4.11 Angular measurements (degrees) comparing control females and orthognathic females showing means, standard deviations and tests for significant differences between control females and orthognathic females.

Measurement	Landmark ¹	Control		Orthognathic		Difference between means	P – Value ²	95% CI for Mean Difference ³	
		Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
Nasiolabial angle	ULA - Sn - Cm	112.1	8.9	105.6	8.0	-6.5	0.020	-11.9	-1.1
	Cm - Sn - Ls	112.9	9.8	104.9	7.8	-8.1	0.006	-13.6	-2.5
Upper Lip Angle	ULA - Sn - TV	6.3	4.7	6.1	5.3	-0.2	0.913	-3.4	3.1
Facial Harmony Angle (Facial Convexity Angle)	G - Sn - Pog	167.7	4.6	170.0	5.7	2.4	0.157	-1.0	5.9
Angle of Total Facial Convexity	G - Prn - Pog	139.4	4.2	142.5	6.1	3.1	0.077	-0.4	6.6
Mentolabial Angle	Li - Sm - Pog	131.9	10.1	124.4	13.4	-7.5	0.063	-15.4	0.4

7. Full names of landmarks and abbreviations are listed in the appendix.
8. p-values calculated using Student's t-test.
9. 95% confidence intervals for the mean difference.
Figures in red indicate statistical significance.
Figures in bold indicate clinical significance.

The results for horizontal measures relative to a True Vertical (TV) are presented in Table 4.12. The majority of horizontal measurements showed a statistically significant difference between the control and orthognathic groups except for:

- glabella to TV
- pronasale to TV
- B point to TV

A point to TV and labiale superior to TV were highly statistically significant ($p < 0.001$).

The female control group had larger measurement values except for:

- glabella to TV
- labiale superior to TV
- upper lip anterior to TV

The majority of linear horizontal measurements were not clinically significant with the exception of:

- labiale inferior to TV (3.3mm)
- pogonion to TV (3.4mm)

Pogonion to TV in the control group had the largest mean difference (3.4 mm). The 95% confidence for the mean difference was greater than 3mm for all measurements except:

- pronasale to TV
- A point to TV

Facial harmony values are presented in Table 4.13. The facial harmony measurements were not significant clinically or statistically except for glabella to A point and glabella to pogonion which were both clinically significant (3.7 mm), (5.1mm) respectively and statistically significant ($p = 0.021$), ($p = 0.034$) respectively. Glabella to pogonion in the

control group showed the largest mean difference (5.1mm). The orthognathic group had larger values for:

- B point to pogonion
- lower lip anterior to pogonion
- glabella to A point

The 95% confidence for the mean difference was greater than 3mm for the following measurements:

- glabella to A point
- glabella to pogonion

Table 4.12 Linear horizontal measurements (mm) relative to True Vertical (TV) comparing control females and orthognathic females showing means, standard deviations and tests for significant differences between control females and orthognathic females.

Measurement (Projection to True Vertical, TV)	Landmark ¹	Control		Orthognathic		Difference between means	P – Value ²	95% CI for Mean Difference ³	
		Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
Glabella to TV	G - TV	-2.5	5.3	-5.3	4.8	-2.8	0.087	-6.0	0.4
Pronasale to TV	Prn - TV	16.3	1.7	15.4	1.7	-0.9	0.121	-2.0	0.2
A point to TV	A - TV	-2.5	1.3	-1.0	1.2	1.6	< 0.001	0.7	2.4
Labiale superior to TV	Ls - TV	-1.0	1.8	1.3	1.7	2.4	< 0.001	1.2	3.5
Upper lip anterior to TV	ULA - TV	-0.7	2.0	1.3	1.9	2.0	0.003	0.7	3.2
Lower lip anterior to TV	LLA - TV	-3.6	2.5	-1.1	3.0	2.5	0.009	0.7	4.3
Labiale inferior to TV	Li - TV	-5.0	2.5	-1.5	2.8	3.3	0.001	1.5	5.0
B point to TV	B - TV	-10.0	4.9	-7.6	4.7	2.4	0.127	-0.7	5.5
Pogonion to TV	Pog - TV	-8.1	3.9	-4.6	4.9	3.4	0.022	0.5	6.4

1. Full names of landmarks and abbreviations are listed in the appendix.

2. p-values calculated using Student's t-test.

3. 95% confidence intervals for the mean difference.

Figures in red indicate statistical significance,

Figures in bold indicate clinical significance

Table 4.13 Facial harmony values (mm), the linear horizontal difference between landmarks as calculated from the True Vertical (TV) comparing control females and orthognathic females showing means, standard deviations and tests for significant differences between control females and orthognathic females.

Measurement (Projection to True Vertical, TV)	Landmark ¹	Control		Orthognathic		Difference between means	P – Value ²	95% CI for Mean Difference ³	
		Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
B point to Pogonion	B - Pog	2.6	1.7	3.6	2.3	1.0	0.142	-0.4	2.3
Lower lip anterior to Pogonion	LLA - Pog	4.8	2.6	4.9	3.0	0.1	0.944	-1.8	1.9
Upper lip anterior to Lower lip anterior	ULA - LLA	2.9	1.6	2.2	1.9	-0.6	0.274	-1.8	0.5
A point to B point	A - B	8.2	2.6	7.2	3.4	-1.0	0.326	-3.0	1.0
Glabella to A point	G - A	0.7	4.9	4.4	4.8	3.7	0.021	0.6	6.8
Glabella to Pogonion	G - Pog	-4.5	7.4	0.5	7.1	5.1	0.034	0.4	9.7

1. Full names of landmarks and abbreviations are listed in the appendix.
 2. p-values calculated using Student's t-test.
 3. 95% confidence intervals for the mean difference.
 Figures in red indicate statistical significance.
 Figures in bold indicate clinical significance.

Table 4.14 show the results for linear vertical measurements. In all cases the measurements were larger in the female orthognathic group except for:

- middle facial third
- vertical nasal length
- length of lower lip (Sti-B)

The following measurements were both clinically significant and statistically significant

- inferior facial third, (p = 0.003)
- length of lower lip (LLS-Me), (p = 0.001)
- chin height, (p = 0.001)

Inferior facial third showed the largest mean difference in the orthognathic group (4.2mm).

The 95% confidence for the mean difference was greater than 3mm for the following measurements:

- middle facial third
- anterior face height
- inferior facial third
- length of lower lip (LLS-Me)
- chin height.

Table 4.14 Linear vertical measurements (mm) comparing control females and orthognathic females showing means, standard deviations and tests for significant differences between control females and orthognathic females.

Measurement	Landmark ¹	Control		Orthognathic		Difference between means	P – Value ²	95% CI for Mean Difference ³	
		Mean	S.D.	Mean	S.D.			Lower Limit	Upper Limit
Middle facial third	G - Sn	68.1	4.2	67.8	4.5	-0.3	0.844	-3.1	2.6
Vertical nasal length	N - Sn	50.0	2.7	49.8	2.6	-0.5	0.528	-2.2	1.2
Anterior face height	N - Me	115.7	6.3	118.4	4.7	2.8	0.113	-0.7	6.3
Inferior facial third	Sn - Me	64.5	3.5	68.7	4.5	4.2	0.003	1.6	6.9
Length of upper lip	Sn – ULI (Sn – Sts) Sn - Sto	20.4	1.5	21.0	2.7	0.6	0.412	-0.9	2.7
Interlabial gap	ULI – LLS (Sts – Sti)	0.8	2.0	1.0	2.0	0.1	0.826	-1.1	1.4
Length of lower lip	LLS - Me	43.3	2.5	46.7	3.4	3.5	0.001	1.5	5.4
	Sti – B	17.0	2.1	16.7	2.1	-0.3	0.684	-1.6	1.1
Vermillion of upper lip	Ls – Sts	7.3	1.1	7.7	1.7	0.4	0.409	-0.6	1.3
Vermillion of lower lip	Li – Sti	9.3	0.8	9.4	1.4	0.1	0.798	-0.7	1.0
Chin height	B - Me	26.0	3.2	30.0	3.7	4.0	0.001	1.7	6.3

1. Full names of landmarks and abbreviations are listed in the appendix.
 2. p-values calculated using Student's t-test.
 3. 95% confidence intervals for the mean difference.
 Figures in red indicate statistical significance.
 Figures in bold indicate clinical significance.

Chapter Five

Discussion

5 Discussion Part I

5.1 The Control Group

5.1.1 Patient recruitment

The overall aim of this study was to compare, using angular and linear measurements, the 2D soft tissue facial profile measurements of a group of post-operative orthognathic surgery patients to a control group of attractive individuals. This aim has been achieved.

5.1.2 The control group

Part I of the study was aimed at recruiting a control group of males and females who were representative of the population of the West of Scotland. As the overall aim of the study was to compare the 2D outcomes following orthognathic surgery in a group of patients from the West of Scotland, the inclusion criteria of the control group were specified to match the demographics of the post-surgical group.

Previous studies assessing 2D facial soft tissue profile measurements to create a database of normal values have used similar inclusion criteria based on ethnic origin and age (Arnett *et al.*, 1999; Fernandez-Riveiro *et al.*, 2002; Fernandez-Riveiro *et al.*, 2003; Anić-Milosevic *et al.*, 2008a; Anić-Milosevic *et al.*, 2008b; Scavone *et al.*, 2008; Kale-Varlk *et al.*, 2008; Malkoç *et al.*, 2009; Uysal *et al.*, 2009). Overall, 112 individuals volunteered to be assessed for potential inclusion in the control group.

5.1.3 Use of a lay panel

A shared appreciation of facial attractiveness and aesthetics exists amongst the general public and across different cultures (Illiffe, 1960; Martin, 1964; Perret *et al.*, 1994). Improvement in facial aesthetics with a view to having a more “normal” or “attractive” appearance is the main motivating factor for the majority of individuals seeking orthognathic surgery (Flanary *et al.*, 1985; Finlay *et al.*, 1995; Rivera *et al.*, 2000). However, it has been shown that opinions differ between clinicians and lay people with respect to what constitutes an attractive facial appearance (Prahl-Anderson *et al.*, 1979; Albino *et al.*, 1984; Bell *et al.*, 1985; Kokich *et al.*, 1999). Ultimately, it is the opinion of the patient and their peers which matters most when subjectively assessing facial attractiveness post-surgery. This study aimed to provide a more patient-orientated assessment of facial attractiveness by using a lay panel to rate the attractiveness of potential recruits to the control group.

5.1.4 Panel composition

Variations in the ideal panel size have been reported. Howells and Shaw, stated that the assessment of photographs to rate facial attractiveness using a panel of two members was valid, reliable and reproducible. Reliability could be further improved by increasing the number of panel members (Howells and Shaw, 1985). Others have advised panel sizes of four members (Peerling *et al.*, 1995) to 12 members (Tedesco *et al.*, 1983b). More recently, Kiekens *et al.* (2007) found a randomly selected panel size of seven to be an ideal panel size. Differing demographic factors between the lay panel and the trial sample can also influence the assessment of facial attractiveness by the lay panel. Such differences include age, gender, ethnicity, professional status, and level of education (Tedesco *et al.*, 1983b; Dunlevy *et al.*,

1987; Flores-Mir *et al.*, 2004). Taking into account these variables this study aimed to minimise potential lay panel influences by selecting a lay panel which consisted consisting of eight Caucasians (four male, four female) from the West of Scotland, aged 18 to 35 years, none of whom had a clinical background or prior experience of orthodontic care. In addition the lay panel was not informed of the research question.

5.2 Methodology

5.2.1 Assessment of facial aesthetics by use of the VAS

The VAS is a consistent and highly valid method of measuring subjective phenomenon (Aitken, 1969; McCormack *et al.*, 1987), and it has been previously used to assess facial and dentofacial aesthetics (Philips *et al.*, 1992a; Philips *et al.*, 1992b; Kokich *et al.*, 1999; Faure *et al.*, 2002; Kiekens *et al.*, 2007). The use of the absolute VAS scores as decided by each rater has its limitations with the overall scores of each rater being relatively independent of each other (Scabbel *et al.*, 2009). This means that the absolute scores are not directly comparable. The sensitivity of the VAS, as a measurement tool, is increased by ranking the scores to enable the relative changes rather than the absolute values to be reported (Elder *et al.*, 2006). A high degree of intra-examiner and inter-examiner agreement when ranking the facial aesthetics using photographs has been previously reported (Roberts-Harry *et al.*, 1992). The present study therefore was based on the ranked VAS to identify the control group. In an attempt to further achieve greater agreement on which subjects to include in the control group; individuals were only chosen if 6 or more of the 8 lay panel ranked them in the top two thirds. The control group was finally made up of 16 males and 24 females considered as “attractive” and “most attractive” by at least six of the lay panel.

In summary, this study uses a control group representative of attractive people in the population of the West of Scotland, as chosen by a lay panel. The goal of facial surgery is to improve facial appearance, but as discussed earlier, the final outcome of improved facial aesthetics should not be decided upon by only clinicians. One of the strengths of this study is that the control group was chosen by the majority of a lay panel which consisted of eight lay people using ranked VAS scores, and who were of a similar background. The rating panel which carried out an impartial assessment of the facial appearances of the volunteers enabled the collection of those facial appearances which the general public considered attractive and most attractive. Analysis of the resulting control group created a data-base of reference 2D soft tissue profile values for 18 to 35 year olds in the West of Scotland.

5.2.2 Use of profile photographs

The aim of treatment has evolved from achieving an “ideal occlusion” to one which recognises that facial aesthetics are of prime importance (Sarver and Ackerman, 2000; Czarnecki *et al.*, 1993). As a result of this concept change, clinical assessment of the soft tissues and aesthetics has a more important role in diagnosis and treatment planning (Ackerman *et al.*, 1999). The facial soft tissues do not always closely correlate to the underlying hard tissues (Subtelny, 1959; Burstone, 1958). Treatment planning is no longer solely devised on dental and skeletal tissues but increasingly on soft tissue aesthetics as the changes in facial soft tissues do not always follow the changes in the underlying skeletal and dental tissues that occur as a result of treatment (Halazonetis, 2007).

The principal aim of this study was to compare post-surgical outcomes of orthognathic surgery to a control group by the objective analysis of soft tissue landmarks on 2D lateral profile facial views. Realistic facial representations are recommended when using a panel of raters to assess

facial aesthetics to ensure the best possible result (Peerlings *et al.*, 1995). In this study the 2D profile image was not shown to the lay panel, as in everyday life, individuals do not generally view others in this way. Instead 3D images of all 112 volunteers were shown to the lay panel as it produced a more true to life view of the overall soft-tissue facial structure (Todd *et al.*, 2005). It could be argued that the use of profile photographs is not a true representation of the patient and these should be superseded with 3D images for analysis. Historically facial soft tissues have been assessed clinically and cephalometrically, with many authors using different soft tissue landmarks and parameters (Riedel, 1950; Burstone, 1958; Subtelny, 1959; Ricketts, 1968; Holdaway, 1984). Hence the need for profile image capture and analysis will remain the current method, since treatment planning based on hard tissues does not provide the best facial aesthetic result (Yogosawa, 1990).

5.2.3 Soft tissue landmark and measurement choice

The soft tissue landmarks and measurements used in the present study were decided by the facial area under examination, reproducibility of landmark identification and the landmarks and measurements recorded in other studies thereby enabling comparison. A total of 16 soft tissue landmarks that were easily visible were selected to improve reproducibility of landmark identification. Measurements involving tragus and trichion were not included as these landmarks have been reported to be difficult to identify and the measurements involving these landmarks unreliable (Fernández-Riveiro *et al.*, 2002). Orthognathic surgery results in soft tissue facial changes mainly at the mid and lower face level; therefore soft tissue landmarks were chosen from these areas. A combination of 6 angular, 9 linear horizontal, 11 linear vertical and 6 facial harmony measurements were recorded and comparison made with other similar studies that analysed soft tissue profiles using a standardised technique (Arnett *et al.*, 1999; Fernández-Riveiro *et al.*, 2002; Fernández-Riveiro *et al.*, 2003; Malkoç *et al.*, 2009; Uysal *et al.*, 2009; Anić-Milosević *et al.*, 2008a; Anić-Milosević *et al.* 2008b; Scavone *et al.*, 2008; Kale-Varlık *et al.*, 2008).

5.2.4 Intra-operator reproducibility of landmark identification

A method error study was carried out to assess the validity and reproducibility of the soft tissue landmark identification. Six images from each of the groups including the male control group, female control group, male orthognathic group and female orthognathic group were randomly selected. Each of the 24 images was landmarked two weeks apart to determine intra-operator error. No systematic errors were observed and all coefficients of reliability were above 90%.

Previous studies that have analysed 2D soft tissue profiles have reported on the method error. Fernández-Riveiro *et al.*, (2003) reported the highest method error, the greatest variability with high standard deviations and large confidence intervals with the nasiolabial angle and the mentolabial angle. Similarly Malkoç *et al.*, (2009); also reported the highest method error with the mentolabial angle. Both Scavone *et al.*, (2008) and Anicÿ-Milosevicÿ *et al.*, (2008a) found that the nasiolabial angle respectively had the highest error.

Anicÿ-Milosevicÿ *et al.* (2008b) reported the highest error of vertical measurements was associated with superior facial third (trichion-glabella), which is suggested to be due to difficulty in identifying trichion. This landmark was not used in the present study owing to the difficulty in identifying the landmark. Kale-Varlk *et al.* (2008) reported that of the measurements in common with the present study, the facial harmony angle was associated with the highest method error. Arnett *et al.* (1999) did not give details of a reproducibility of landmarks and measurements while Uysal *et al.* (2009) reported on the method error of measurements not used in the present study.

5.3 Analysis of the Attractive Group

In the West of Scotland control group there were no statistically significant differences between the males and females for angular measurements. The nasiolabial angle was larger or more obtuse, by 4.1°, in the female group than the male group. All remaining facial angles including facial harmony angle, angle of total facial convexity and mentolabial angle were smaller in the female control group. As no angular measurements were statistically significant between male and females this would indicate that males and females from the control group have a broadly similar facial profile with respect to angular measurements.

The angular measurements found in the present study were of a similar range and variation to the previous studies, Table 5.1. The non-statistically significant difference in nasiolabial angle between males and females was in agreement with a previous study whose inclusion criteria were similar to the present study (Fernández-Riveiro *et al.*, 2003). However other studies reported significant differences for these angles and it is interesting to note that these studies specified a particular facial form as part of the inclusion criteria (Anić-Milosević *et al.*, 2008a; Kale-Varlık *et al.*, 2008; Malkoç *et al.*, 2009). The differences in the findings were numerically small and may indicate differences between the population groups, due to the different inclusion criteria and the method in which the samples were selected.

All linear horizontal measurements relative to a True Vertical reference line through subnasale were larger in the female group compared to the male group except for glabella to TV and Pronasale to TV. There was no clinical or statistical difference between any of the measurements for the two groups. Many of the differences were minimal and not clinically significant; however the 95% confidence for the mean difference was greater than 3mm for glabella to TV, B point to TV and pogonion to TV. This would indicate that males have more prominent chins and more retrusive foreheads than females relative to the True Vertical through subnasale. The remaining horizontal measurements relative to TV are similar for both males and females.

Table 5.1 Table comparing angular measurements between this study and previous studies (continued on next page). Values in **bold** indicate statistic significance between males and females within the study.

Study Measurement (mm)		Present Study Male	Present Study Female	Arnett <i>et al.</i> (1999) Male	Arnett <i>et al.</i> (1999) Female	Uysal <i>et al.</i> (2009) Male	Uysal <i>et al.</i> (2009) Female	Anicÿ- Milosevicÿ <i>et al.</i> (2008a) Male	Anicÿ- Milosevicÿ <i>et al.</i> (2008a) Female	Fernández- Riveiro <i>et al.</i> (2003) Male	Fernández- Riveiro <i>et al.</i> (2003) Female
ULA-Sn-Cm	Mean	108.5	112.1	106.4	103.5	106.8	108.1				
	S.D	11.6	8.9	7.7	6.8	10.6	8.3				
Cm-Sn-Ls	Mean	108.8	112.9					105.42	109.39	105.2	107.57
	S.D	12.1	9.8					9.52	7.84	13.28	8.5
ULA-Sn-TV	Mean	5.6	6.3	8.3	12.1	8.7	12				
	S.D.	4.1	4.7	5.4	5.1	6.4	7.1				
G-Sn-Pog	Mean	169.9	167.7	169.4	169.3	167.4	166.6	168.8	169.1	168.2	167
	S.D.	4.6	4.6	3.2	3.4	5.3	5	4.97	4.69	4.96	5.36
G-Prn-Pog	Mean	141.2	139.4							139.9	139.2
	S.D.	4.5	4.2							5.38	4.5
Li-Sm-Pog	Mean	133.3	131.9					129.26	134.5	130.75	131.45
	S.D.	11.5	10.1					9.6	9.1	9.6	11

Measurement (mm) \ Study		Malkoç <i>et al.</i> (2009) Male	Malkoç <i>et al.</i> (2009) Female	Kale-Varlık <i>et al.</i> (2008) Male	Kale-Varlık <i>et al.</i> (2008) Female	Scavone <i>et al.</i> (2008) Male	Scavone <i>et al.</i> 2008 Female
Ula-Sn-Cm	Mean					108.9	113.9
	S.D					11.6	10.8
Cm-Sn-Ls	Mean	101.09	102.94	98.7	104.4		
	S.D	10.19	10.43	13.7	12.7		
ULA-Sn-TV	Mean						
	S.D.						
G-Sn-Pog	Mean	170.6	168.8	169.3	167.9		
	S.D.	6.15	5.44	5.3	4.7		
G-Prn-Pog	Mean	142.4	142.6				
	S.D.	5.4	5.3				
Li-Sm-Pog	Mean	130.2	137.2	126.3	125.6		
	S.D.	8.5	10.9	4.3	4		

These horizontal measurements relative to TV results are similar to the previous studies in both magnitude and variability, Table 5.2. An interesting observation is the similarity of the nose tip position, between all the studies, irrespective of forehead position, Figure 5.1 and 5.2. It would appear that the maxillary soft tissue (i.e. upper lip position) was more retrusive in relation to TV for the West of Scotland population than for the other studies. With respect to the forehead, the American control group had much more upper and lower lip protrusion, i.e. fuller lips than any of the other control groups including the present study. It would also appear that chin point in the American control group is more anteriorly positioned together with the lower lip. This would tend to indicate that the single individual responsible for choosing the “control” individuals favoured a straighter facial profile with full lips (Arnett *et al.*, 1999). The positions of the forehead for two studies were very similar (Arnett *et al.*, 1999; Uysal *et al.*, 2009), yet the lips were more protrusive in the American control group when compared to the Turkish group. A possible reason for this is the obvious difference in inclusion criteria.

Harmony values are a measure of facial balance and harmony between different soft tissue facial landmarks, which is an important element of beauty. Facial balance is determined by assessing the position of two soft tissue landmarks relative to each other. Facial harmony values are the horizontal distance between two landmarks perpendicular to a True Vertical (TV) reference line through subnasale.

Table 5.2 Table comparing linear horizontal measurements relative to a True Vertical reference line through subnasale between this study and previous studies. Values in **bold** indicate statistic significance between males and females within the study.

Study Measurement (mm)		Present Study Male	Present Study Female	Arnett <i>et al.</i> (1999) Male	Arnett <i>et al.</i> (1999) Female	Uysal <i>et al.</i> (2009) Male	Uysal <i>et al.</i> (2009) Female	Anić- Milosević <i>et al.</i> (2008b) Male	Anić- Milosević <i>et al.</i> (2008b) Female	Scavone <i>et al.</i> (2008) Male	Scavone <i>et al.</i> 2008 Female
G-TV	Mean	-4.1	-2.5	-8	-8.5	-8.4	-8.4			-7.4	-5.5
	S.D	6	5.3	2.5	2.4	0.5	0.3			3.8	4.3
Prn-TV	Mean	16.7	16.3	17.4	16	17.4	16.1	16.9	15.6	15.3	13.9
	S.D	2.4	1.7	1.7	1.4	2.6	1.8	1.8	1.9	2.1	1.6
A-TV	Mean	-2.3	-2.5	-0.3	-0.1	-0.2	-0.2				
	S.D.	1.1	1.3	1	1	1.8	1.2				
Ls-TV	Mean	-0.6	-1					1.3	1.3		
	S.D.	1.8	1.8					1.8	1.4		
ULA-TV	Mean	-0.7	-0.7	3.3	1.2	1.9	1.2			2.3	1.3
	S.D.	1.7	2	1.7	1.9	2.8	1.9			1.8	1.8
LLA-TV	Mean	-3.4	-3.6	1	1.9	-1	-1.2			0	-1
	S.D	2.4	2.5	2.2	1.4	3.8	2.7			2.2	2.8
Li-TV	Mean	-4.1	-5					-2	-1		
	S.D	2.8	2.5					2.5	1.9		
B-TV	Mean	-9.9	-10	-7.1	-5.3	-10.5	-9.1	-9.5	-7.4	-7.1	-7.8
	S.D.	3.9	4.9	1.6	1.5	4.7	3.7	3.1	2.7	3.4	4.1
Pog-TV	Mean	-6	-8	-3.5	-2.6	-6.4	-6.4	-6.4	-5.6	-4.5	-6.4
	S.D.	5.1	3.9	1.8	1.9	5.6	5	3.9	3.4	5.1	5.2

Figure 5.1 Diagram showing the horizontal measurements relative to a TV for the present and previous studies for females, showing the common landmarks.

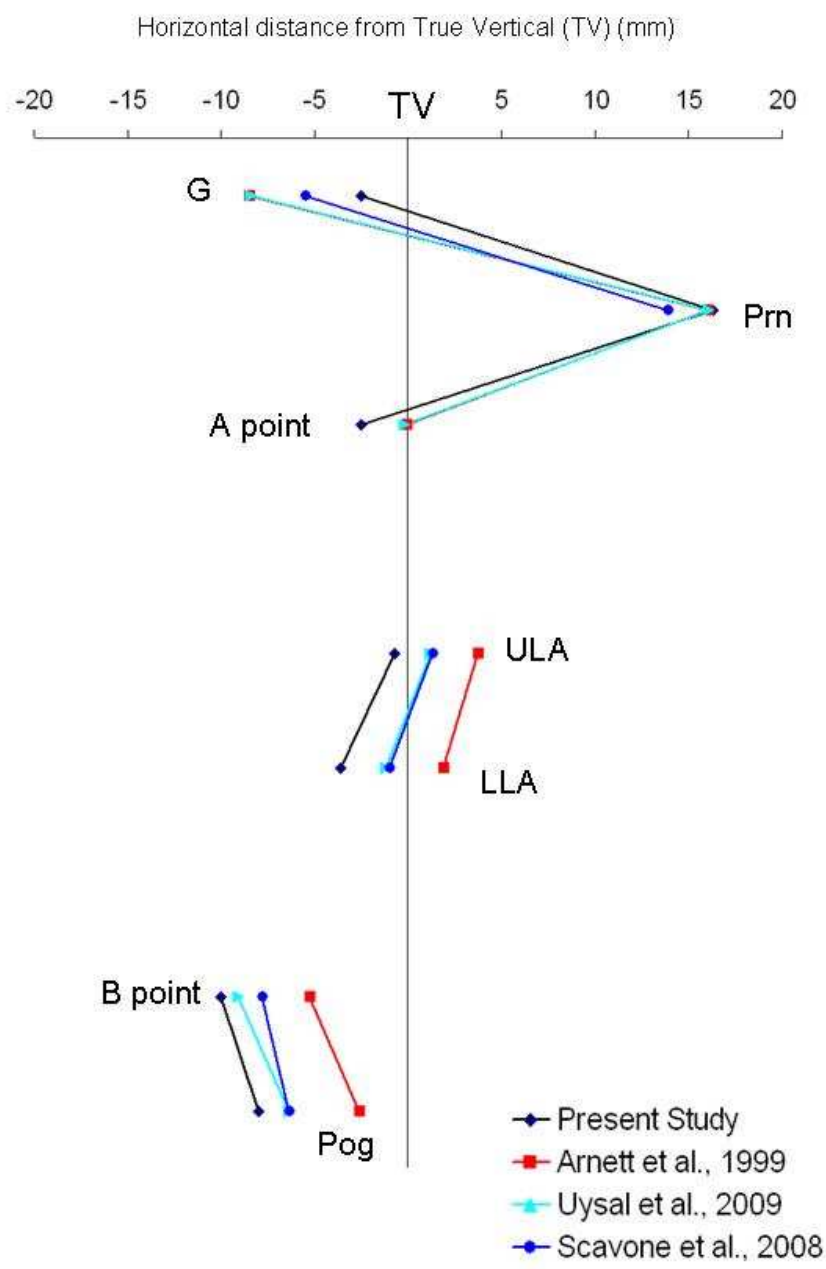
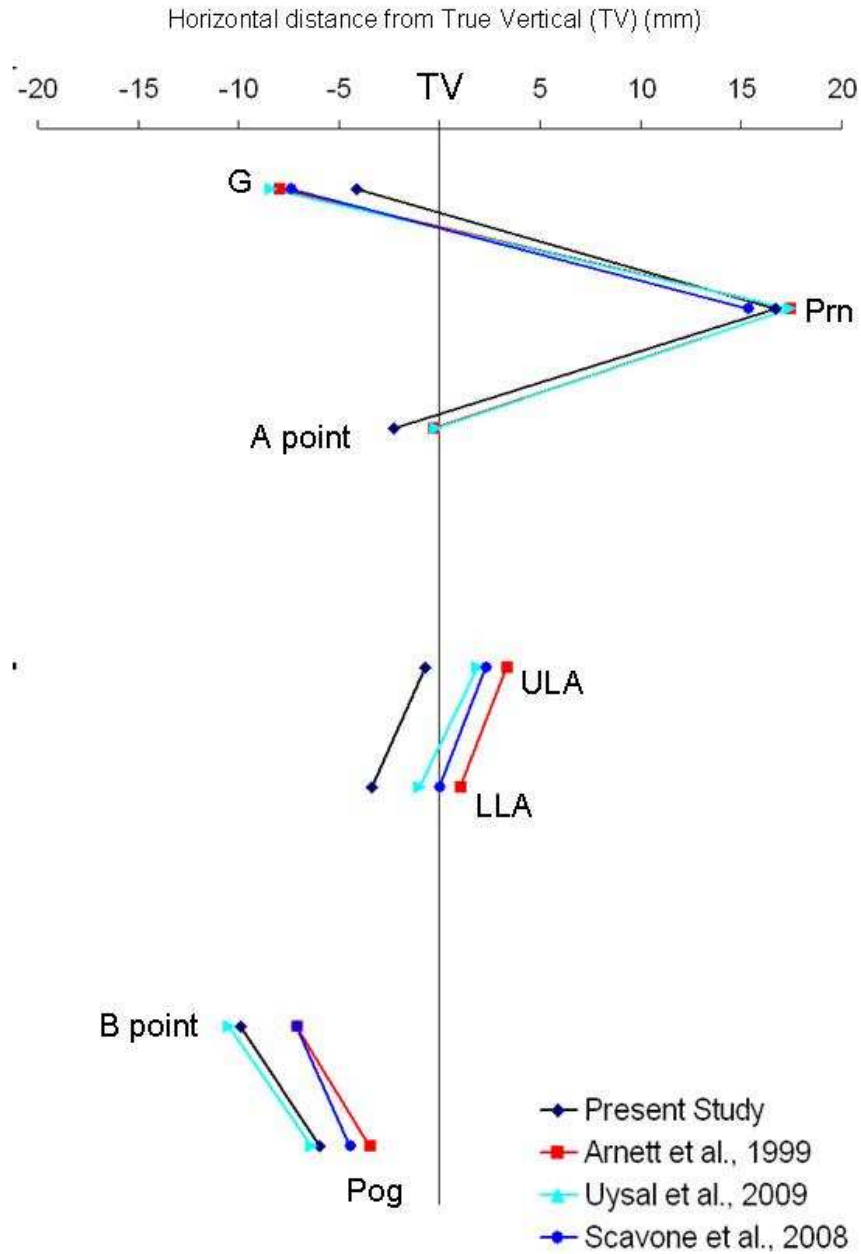


Figure 5.2 Diagram showing the horizontal measurements relative to a TV for the present and previous studies for males, showing the common landmarks.



Harmony values assess four areas of facial balance including; intramandibular parts, interjaw parts, orbit to jaws and the total face. Intramandibular harmony measurements assess chin projection to lower lip position (LLA-Pog) and soft tissue B point (B-Pog) relative to TV. Interjaw harmony values assess the position of soft tissue B point to soft tissue A point (A-B) and upper lip relative to lower lip (ULLA-LLA) relative to TV. Interjaw harmony is determined by upper and lower incisor inclination, maxillary occlusal plane and soft tissue thickness. Total facial harmony values assesses the position of the forehead to the upper jaw (G-A) and to the chin (G-Pog) relative to TV. Combined with the facial harmony angle these values give an overall view of facial balance.

The intramandibular relationships were not clinically significant, and the 95% confidence for the mean difference was less than 3mm. However, B point to Pogonion, which assesses chin projection to soft tissue B point relative to TV, was statistically significant ($p=0.045$). Overall, many of the differences were minimal and not clinically significant in this sample. However there was a clinically significant difference for glabella to pogonion and the 95% confidence for the mean difference was greater than 3mm for glabella to A point. Overall, the harmony values indicate that male and female controls are broadly similar for these values, however they differ with respect to position of forehead to the upper jaw and forehead to chin position relative to TV. In that the linear horizontal distance between forehead and upper jaw relative to TV is larger in males compared to females, the linear horizontal distance between forehead and chin point relative to a TV is smaller in males compared to females. The intramandibular and interjaw relations are similar, the control males and females differ with respect to total facial harmony as reflected in the measurements glabella to A point and glabella to pogonion.

The majority of harmony values were not different for the present study and the other studies that reported on them (Arnett *et al.*, 1999; Uysal *et al.*, 2009). The most marked difference was in the measurements glabella to A point and glabella to pogonion, Table 5.3. This tended to indicate that in the West of Scotland control group, relative to the forehead, both the soft tissue maxillary and mandibular positions were retrusive compared to the other studies (Arnett *et al.*, 1999; Uysal *et al.*, 2009). This is supported by the horizontal measurements relative to a TV results.

All vertical measurements were smaller in the female group compared to the male group except for vermillion of upper lip and vermillion of lower lip. Differences in the anterior face height, inferior face height, length of lower lip and chin height were clinically and statistically significant ($p < 0.001$). In addition to the previously mentioned clinically significant measurements, the 95% confidence for the mean difference was greater than 3mm for middle facial third, length of lower and vertical nasal length which was statistically significant ($p = 0.002$). These results indicate that females have smaller vertical facial lengths compared to males.

The following linear vertical measurements were statistically significantly different for male and females; nasal length, anterior face height, inferior facial third, length of upper lip, length of lower lip and chin height. The mean value for these vertical measurements

Table 5.3 Table comparing harmony values measurements between this study and previous studies. Values in **bold** indicate statistic significance between males and females within the study.

Study Measurement (mm)		Present Study Male	Present Study Female	Arnett <i>et al.</i> (1999) Male	Arnett <i>et al.</i> (1999) Female	Uysal <i>et al.</i> (2009) Male	Uysal <i>et al.</i> (2009) Female
B-Pog	Mean	3.9	2.6	3.6	2.7	4	2.7
	S.D	2	1.7	1.3	1.1	2.2	2.1
LLA-Pog	Mean	4.1	4.8	4.4	4.5	5.3	5.2
	S.D	3.1	2.6	2.5	2.1	3.5	3.4
ULA-LLA	Mean	2.9	2.9	2.3	1.8	2.9	2.4
	S.D.	1.9	1.6	1.2	1	1.8	1.6
A-B	Mean	7.6	8.2	6.8	5.2	8.8	7.2
	S.D.	3.8	2.6	1.5	1.6	3.8	3.3
G-A	Mean	2.4	0.7	7.8	8.4	6.7	6.5
	S.D.	5.7	4.9	2.8	2.7	1.8	1.1
G-Pog	Mean	-1.2	-4.5	4.6	5.9	1.9	1.9
	S.D.	9.5	7.4	2.2	2.3	5.6	5.1

was smaller for females compared to males indicating that a common finding in all the studies that reported on these vertical measurements females had smaller vertical facial lengths. Again it was interesting to note that the American control group had longer faces than the West of Scotland group. This was evident as a larger total anterior face height, Table 5.4.

Both the vermillion of the upper lip (Ls-Sts), (Ls-Sto) and the vermillion of the lower lip (Li-Sti) were not statistically significant for the studies that recorded these measurements in Table 5.4. All the studies that reported on these measurements found that the mean value was larger for females compared to males; however it was not statistically significant. The remaining vertical measurements were similar between all the control groups.

It is obvious that there is a difference between male and female faces. Therefore, unlike other studies, it is not appropriate to group them together for analysis (Weinberg *et al.*, 2004; Wong *et al.*, 2008). The comparison of the present results with previous studies, particularly the American control group, show that there is a difference between this group and the European control group in terms of mainly horizontal and vertical measurements. The American control group have longer faces, with straighter profiles and much fuller lips.

Table 5.4 Table comparing vertical measurements between this study and previous studies.

Study Measurement (mm)		Present Study Male	Present Study Female	Arnett <i>et al.</i> 1999 Male	Arnett <i>et al.</i> 1999 Female	Uysal <i>et al.</i> 2009 Male	Uysal <i>et al.</i> 2009 Female	Anicÿ- Milosevicÿ <i>et al.</i> (2008b) Male	Anicÿ- Milosevicÿ <i>et al.</i> (2008b) Female	Fernández- Riveiro <i>et al.</i> (2003) Male	Fernández- Riveiro <i>et al.</i> (2003) Female
G-Sn	Mean	69.3	68.1					67.94	64.69	72.1	68.7
	S.D	3.4	4.2					4.35	3.39	4.88	4.66
N-Sn	Mean	53.2	50.3					53.8	50.27	52.53	49.86
	S.D	2.5	2.7					2.74	2.65	4.12	3.7
N-Me	Mean	127.9	115.7	137.7	124.6	135.7	124.9				
	S.D.	7.8	6.3	4.7	4.7	6.3	5.8				
Sn-Me	Mean	73.8	64.5	81.1	71.1	76.5	68.7	71.16	63.47	71.4	65.4
	S.D.	5.5	3.5	4.7	3.5	5.5	4.5	4.7	3.38	5.69	4.33
Sn-Sts (ULI) (Sn-Sto)	Mean	22.2	20.4	24.4	21	23.4	20.4	23.55	20.57	23	21.43
	S.D.	1.8	1.5	2.5	1.9	3	2.9	2.64	2.01	2.6	1.83
ULI-LLS	Mean	1.3	0.8	2.4	3.3	1.2	1.4			0.29	0.62
	S.D.	2.4	2	1.1	1.3	1.6	1.3			0.76	1.5
LLS-Me	Mean	50.1	43.3	54.3	46.9	52	46.9				
	S.D	4.1	2.5	2.4	2.3	3.7	3.1				
Sti-B (Sto-Me)	Mean	18.1	17					47.6	42.9	19.01	17.48
	S.D	3.1	2.1					3	2.48	2.49	1.93
Ls-Sts (Ls-Sto)	Mean	6.8	7.3					8.39	8.52	7.27	7.43
	S.D.	1.5	1.1					1.29	1.35	1.65	1.39
Li-Sti	Mean	8.5	9.3							8.36	8.59
	S.D.	1.9	0.8							1.78	1.52
B-Me	Mean	32.6	26					28.63	25.21	29.09	25.85
	S.D.	3.9	3.2					2.22	2.24	2.93	2.48

5.4 Future Considerations

- The images from the attractive sample were viewed by the lay panel only in one sitting. Thus intra-rater reproducibility in rating of facial attractiveness could not be determined. Hönn *et al.* (2008) recommend that the assessment rating by the panel should be repeated at least two weeks later following the initial assessment to eliminate memory bias and thereby improve the reproducibility and validity of the study. This has been employed by many researchers, with a minimum of one week between assessments (Roberts-Harry *et al.*, 1992; Peerlings *et al.*, 1995; Lundstrom *et al.*, 1987). To further improve the study further investigation into intra-rater reproducibility would be appropriate.
- Profile photographs provide 2D information from only one view of the face, thereby ignoring the 2D measurements from other parts of the face including frontal and three quarter views. A future consideration would be to incorporate images of the face from different views, alternatively 3D capture. A photograph is a 2D representation of a 3D object and there is loss of depth of field, which does not occur with 3D capture. Extending the study to involve 3D measurements would provide a more comprehensive analysis of the facial soft tissue differences that exist between males and females.
- There is no clinically significant value for angular measurements which makes interpretation less clear. Further study evaluating a clinically significant value for angular measurements is recommended.

5 Discussion Part II

5.5 The Orthognathic Group

5.5.1 Patient recruitment

The post-operative orthognathic group was randomly recruited from the Dentofacial Deformity clinics at the Glasgow Dental Hospital and the Southern General Hospital Glasgow. The orthognathic control group was similarly matched with the control group with respect to; age (18-35 years), ethnicity and place of origin. Members of the orthognathic group were required to be a minimum of six months post-operative orthognathic surgery to allow sufficient soft tissue healing and resolution of post-operative swelling (Kau *et al.*, 2007). In total 16 males aged between 16-34 years (mean age 22.4 years) and 17 females with an age range of 17-35 years (mean age 23.8 years) were recruited to the post-operative orthognathic group.

5.5.2 Surgical procedures

The type of orthognathic procedure was not considered an important variable of the study as all surgical procedures were provided with the aim of correcting an underlying dentofacial deformity and “normalizing” the patient. The surgical procedures undergone by the male orthognathic group included; 13 males were treated with maxillary advancements, 6 males were treated with mandibular setbacks and 4 males had mandibular advancements. The surgical procedures undergone by the female orthognathic group included; 12 females who had maxillary advancements and 8 females who had mandibular advancements, while one female had a mandibular setback procedure.

5.6 Male Orthognathic Group Compared to the Male Control Group

There were no statistically significant differences between the control males and orthognathic males with respect to angular measurements. The mentolabial angle in the orthognathic group showed the largest mean difference (6.2°). The mentolabial angle is dependent on lower lip soft tissue thickness, chin soft tissue prominence and antero-posterior position of the chin. The larger mentolabial angle observed in the male orthognathic group may be due to the majority of patients presenting with class III skeletal patterns. These patients often initially present with a Class III incisor with dental compensation with retroclination of the lower labial segment and lower lip; this leads to an increase in the mentolabial angle. As the majority of surgical procedures were maxillary advancement procedures for the correction of a class III skeletal pattern, this may suggest that full lower arch dental decompensation was not achievable or desired (partial decompensation). Overall the orthognathic male group had similar angular facial measurements suggesting that treatment had successfully corrected any potential angular discrepancies between the groups.

The majority of linear horizontal measurements were smaller in the male orthognathic group except for glabella to TV. The 95% confidence for the mean difference was greater than 3mm in the majority of measurements except for pronasale to TV, A point to TV and labiale superior. B point to TV was clinically significant (3.3mm) in this sample. The results indicate that the male orthognathic group have more protrusive upper and lower lips and chins compared to the male control group. A possible explanation may be that the majority of surgical procedures were maxillary advancement procedures to correct a clinically retrusive maxillary position accepting an already slightly prominent chin. The measurement glabella to

TV, indicates the linear horizontal position of forehead relative to the TV. As this landmark is unlikely to change with surgery, this absolute value indicates that the males orthognathic group's forehead position is more retrusive compared to the control group. An alternative inference may be that the maxilla in the surgical group is too far forward, therefore the TV line passing through subnasale is also too far forward and therefore the forehead appears retrusive relative to TV. In either case the discrepancy between glabella and A point is different between the groups; this is supported by the large difference in the harmony value, glabella and A point, seen between the groups.

The 95% confidence of the mean difference was greater than 3mm for glabella to A point (G-A) and A point to B point (A-B). The results indicate that interjaw relations, as reflected by (A-B), are different between the groups. The groups differ with respect to total facial harmony as reflected in the glabella to pogonion values and glabella to A point. Over all the results indicate that intramandibular harmony has been achieved by the post-operative orthognathic male group, but total facial harmony has not been achieved. In the male orthognathic group the relative linear horizontal position of forehead to chin point is more prominent relative to TV and is a larger distance compared to male controls. The results indicate that surgery is correcting the intramandibular harmony but not correcting the relationship of glabella to pogonion which is a measure of total facial harmony.

The majority of linear vertical measurements were slightly larger in the male orthognathic group compared to the male control group except for vertical nasal length, anterior face height, interlabial gap and chin height. The vermillion of the upper lip was statistically significant ($p = 0.003$). The 95% confidence for the mean difference was greater than 3mm for all measurements except interlabial gap and vermillion of lower lip. The results indicate that the

vertical measurements were generally similar between the two groups; however the majority of linear vertical measurements were slightly larger in the male orthognathic group.

5.7 Female Orthognathic Group Compared to the Female Control Group

The nasiolabial angle was smaller in the female orthognathic groups, with the largest mean difference between the groups of 8.1° . Both nasiolabial angles (ULA-Sn-Cm) and (Cm-Sn-Ls) were statistically significant ($p=0.020$) and ($p=0.006$) respectively.

Overall, the orthognathic female group had similar angular facial measurements suggesting that treatment was successful; however in the female orthognathic group both nasiolabial angle were smaller than the control group, which was statistically significant. Again the maxillary advancement procedures will have the greatest effect on nasiolabial angle change. The results are tending to indicate that the advancement is moving the upper lip forward and reducing the nasiolabial angle. The clinical significance of this change remains unknown.

The majority of horizontal measurements showed a statistically significant difference between the female control and female orthognathic groups, except for glabella to TV, Pronasale to TV and B point to TV. Both pogonion to TV and labiale inferior to TV were clinically and statistically significant. The results indicate that in the orthognathic female group both the upper and lower lips and chin were further forward relative to TV compared to the control group. As discussed earlier, this may be due to position of the forehead or the TV line, but again the harmony values support this result.

Most facial harmony values were not clinically or statistically significant except for glabella to A point and glabella to pogonion which were both clinically significant (3.7mm) and (5.1mm) respectively and statistically significant ($p = 0.021$) and ($p = 0.034$) respectively. Overall the results indicate that both intramandibular relations and interjaw relations were broadly similar for both groups, however total facial harmony was not achieved by the orthognathic group as reflected by glabella to A point and glabella to pogonion values. Surgery is correcting the intramandibular harmony and interjaw relations but not correcting total facial harmony.

The majority of vertical measurements were slightly larger in the female orthognathic group compared to the female control group except for middle facial third, vertical nasal length and length of lower lip (Sti-B). The 95% confidence for the mean difference was greater than 3mm for the following measurements middle facial third, anterior face height, inferior facial third, length of lower lip (LLS-Me) and chin height. Inferior facial third, length of lower lip (LLS-Me) and chin height were clinically and statistically significant. The results indicate that the female orthognathic patients had greater mid and lower facial heights compared to the female control group.

5.8 Future Considerations

- The comparison of the 2D facial soft tissue measurements of potential orthognathic patients to the collected population's normative values provides the first stages of an objective measurement of a subjective characteristic. Further development may allow patients to see clearly how closely their facial appearance correlates with what is considered attractive by the general public.

- Currently a software prediction programme Dolphin (Dolphin Imaging, Chatsworth, USA) is based on the results of Arnett *et al.* (1999). This planning software utilises the 2D soft tissue values based on white American models with good facial balance as assessed by one author. Following the results of the present study, the appropriateness of treatment planning West of Scotland patients using this software now needs further investigation.
- An assessment of the appropriateness of the diagnosis, treatment planning and outcome of treatment provided could be carried out by recording facial measurements before and after surgery and recording the type of surgical procedure which produced the result. A lay panel could also be used to assess the aesthetic improvement by viewing the sample before and after treatment.

Chapter Six

Conclusions

6 Conclusions

6.1 First Aim

To determine the 2D lateral soft tissue facial measurements of an “attractive” group of West of Scotland males and females between the ages of 18 and 35 as selected by a panel of laypeople.

Conclusions

- A database of 2D photographic images of 24 females and 16 males from the West of Scotland has been created based on the selection of 8 laypeople. Simple angular and linear measurements have been recorded.
- Males and females differ from one another with respect mainly to the linear measurements recorded, especially the linear vertical measurements. Males have longer faces and more prominent chins.
- The null hypothesis that there is no difference between the 2D soft tissue measurements between males and females in the attractive group in this study was not upheld.

6.2 Second Aim

To determine whether post-operative orthognathic patients look attractive based on objective measurements of 2D soft-tissue facial landmarks.

Conclusions

- A database of 2D images of 17 females and 16 males post-orthognathic surgery and from the West of Scotland was collated from the Dentofacial Clinics at Glasgow Dental Hospital.
- The facial morphology of the male orthognathic sample was found to be similar to the male attractive group except that the male orthognathic group have more protrusive upper and lower lips and chins compared to the male control group. Surgery appears to be correcting the intramandibular harmony and interjaw relations but not correcting total facial harmony.
- The facial morphology of the female orthognathic group was similar to the female attractive group except that the female orthognathic group had smaller nasiolabial angles, longer mid and lower facial heights and upper and lower lips and chin which were further forward relative to TV compared to the control group.
- The null hypothesis that there is no difference between the 2D soft tissue measurements obtained from a group of attractive subjects and those of the post-surgical treatment group in this study was not upheld. Again, surgery appears to be correcting the intramandibular harmony and interjaw relations but not correcting total facial harmony.

Chapter Seven

Appendices

7 Appendices

7.1 Appendix I – Copy of the Ethics Letter

Acute Services Division

NHS
Greater Glasgow
and Clyde

West Glasgow Ethics Committee 2
Western Infirmary
Dumbarton Road
Glasgow
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20 May 2008

Dr Balvinder Khambay
Level 5,
Orthodontic Department,
Glasgow Dental Hospital & School,
378 Sauchiehall Street,
Glasgow
G2 3JZ

Dear Dr Khambay

Study title: A pilot study to investigate the two & three dimensional features of the normal West of Scotland face and the development of an assessment tool to evaluate the success of orthognathic surgery.

REC reference: 07/S0709/59

Amendment number:

Amendment date: 20 April 2008

The above amendment was reviewed at the meeting of the Committee held on 20 May 2008.

Ethical opinion

The members of the Committee present gave a favourable ethical opinion of the amendment on the basis described in the notice of amendment form and supporting documentation.

Approved documents

The documents reviewed and approved at the meeting were:

Document	Version	Date
Notice of Substantial Amendment (non-CTIMPs)		20 April 2008
Covering Letter		20 April 2008

Membership of the Committee

The members of the Committee who were present at the meeting are listed on the attached sheet.

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Acute Services Division

R&D approval

All investigators and research collaborators in the NHS should notify the R&D office of the relevant NHS care organisation of this amendment and check whether it affects R&D approval of the research.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

07/S0709/59:

Please quote this number on all correspondence

Yours sincerely


PP **Andrea Torrie, Manager - West Glasgow LREC's**

E-mail: andrea.torrie@ggc.scot.nhs.uk

Enclosures

List of names and professions of members who were present at the meeting and those who submitted written comments

Copy to:

✓ R & D Department

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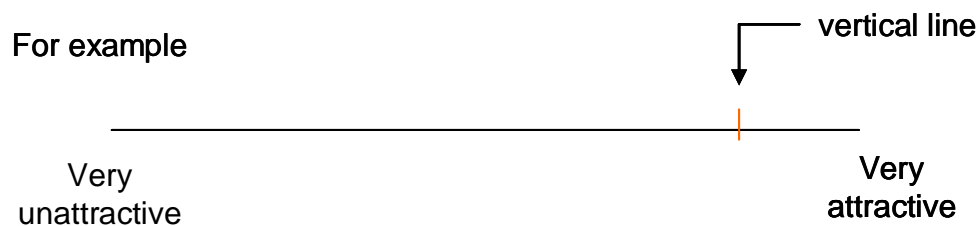
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7.2 Appendix II - Rating VAS Instructions

Thank you for agreeing to take part in this study.

You will be shown 112 images of peoples faces, each will be on the screen for about 30 seconds and each will rotate to provide you with a “3D view” of the face.

Using the line below please indicate with a vertical line where you would place the face on the line given that one end represents “very unattractive” and the other “very attractive”.



We are interested in “facial harmony” since attraction encompasses many other factors; therefore please **IGNORE** the following facial features whilst carrying out the assessment.

- Skin condition
- Hair
- Eyes
- Ears

Many thanks

Dr B.S.Khambay

Thank you for agreeing to take part in this study.

You will be shown 112 images of peoples faces, each will be on the screen for 30 second and each will rotate to provide you with a “3D view” of the face.

Using the line below please indicate with a vertical line where you would place the face on the line given that one end represents “very unattractive” and the other “very attractive”.

For example



Very unattractive Very attractive

No.1




Very unattractive Very attractive

No.2



Very unattractive Very attractive

No.3



Very unattractive Very attractive

No.4



Very unattractive Very attractive

Chapter Eight

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